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AERO/SPACE ENGINEERING

REVIEW OF CURRENT AND FUTURE TRENDS IN AIRCRAFT • MISSILES • ROCKETS • SATELLITES • SPACECRAFT

Space Applications for Rocket Vehicles . . . p. 38

SEPTEMBER / 1959

GUEST EDITORIAL: *H. Guyford Stever discusses the modern partnership of Engineering and Science* . . . p. 37

XUM

HIGH-SPEED GEAR PUMPS FOR THE NEXT GENERATION OF AIRCRAFT·MISSILES·SPACECRAFT

High performance hydraulic pumps by Eastern are uniquely suited to the exacting operating requirements demanded in the craft of tomorrow.

Check these Eastern gear pump features — do they suggest a solution to your present design problem?

Small size: Eastern gear pumps are the smallest, lightest made. Airborne servo system pump shown delivers 1.5 gpm @ 1500 psig — measures only 1⅞" X 1⅞" X 2¾", weighs 9 oz.

Wide performance range: pumps available have theoretical displacements from .0016 to .0419 cu. in. per revolution — flow from .025 to 2.0 gpm, pressures from 0 to 2000 psig, at speeds to 24,000 rpm. Weights with motor range from 1.5 to 8.5 lbs.

Unaffected by extreme environments: rugged, reliable Eastern units take loads to 50g in stride — shrug off temperature differentials to meet MIL specs.

Flexibility, economy: mass-produced components can be teamed into the precise configuration you need. Creatively-engineered custom pumps also available.

Contact Eastern for creative contributions to help you solve your hydraulic pump or power problems. Write for Bulletin 360 — your complete new guide to Eastern aviation products.

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HYDRAULIC POWER • ELECTRONIC COOLING • REFRIGERATION-TYPE COOLING • PRESSURIZATION-DEHYDRATION • SERVO-VALVE HYDRAULIC SYSTEMS •

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first
inflatable
radome of
uniform thickness
throughout!

Assures minimum attenuation with maximum tracking accuracy

1 **THE CHALLENGE:** always before, overlapping sections of rubberized fabric have caused a certain amount of beam distortion at the seams.

2 **THE GOODYEAR ANSWER:** an entirely new kind of inflatable radome construction. Now, gore patterns butt together—joined by an improved sealing compound—with only a hairline of separation between them. There is no bulky overlapping—no double-thick seam. Fabric has been improved too. It's a new high-strength synthetic material that weighs 20% to 25% *less* than previously used fabrics—requires no periodic painting—assures all-weather protection.

3 **WHAT IT MEANS TO YOU.** New uniform thickness radomes by Goodyear provide better electrical transparency, minimum beam shift and boresite error, unparalleled mobility, improved transmission qualities on high and low frequencies. Since they weigh less, they're easier to transport. Since they're exceptionally strong, they can withstand wind velocities to 150 m.p.h. And they are ideally suited for tactical operations—can even be air-dropped into remote areas and quickly inflated at the erection site. Available in sizes to 100 feet in diameter.

4 **FOR MORE INFORMATION** on this major advance in radome development—including engineering brochures and fabric samples—call or write The Goodyear Tire & Rubber Company, Aviation Products Division, Dept. I-1711, Akron 16, Ohio, or Los Angeles 54, California.

AVIATION PRODUCTS BY **GOODYEAR**

More aircraft land on Goodyear Tires, Wheels and Brakes than on any other kind

XUM

On our cover

Ability of a space vehicle to maneuver, and to rendezvous with other spatial objects at the will of its crew, is essential to the conquest of space, according to Everett T. Welmers, AFIAS, Bell Aircraft Corporation Director of Plans and Programs. His current thoughts on "Space Applications for Rocket Vehicles" are presented exclusively in this issue of Aero/Space Engineering, and such a vehicle— a manned glider with a large rocket engine—has been envisioned for our cover by Carlton F. Zoschke, Technical Publications, also of Bell. Attitude control will permit orienting thrust relative to flight path, thus changing the plane or radius vector of the orbit. Dr. Welmers lists velocity increments and energy requirements for such maneuvers and discusses problems requiring effort, to conclude that a maneuverable manned space glider is feasible in the light of technical knowledge.

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"The prestige magazine of the Aerospace Industry"

AERO/SPACE ENGINEERING

VOLUME 18 / NUMBER 9 **September 1959**

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The National Scene **23** National Turbine-Powered Air Transportation Meeting to Be Held November 17–18
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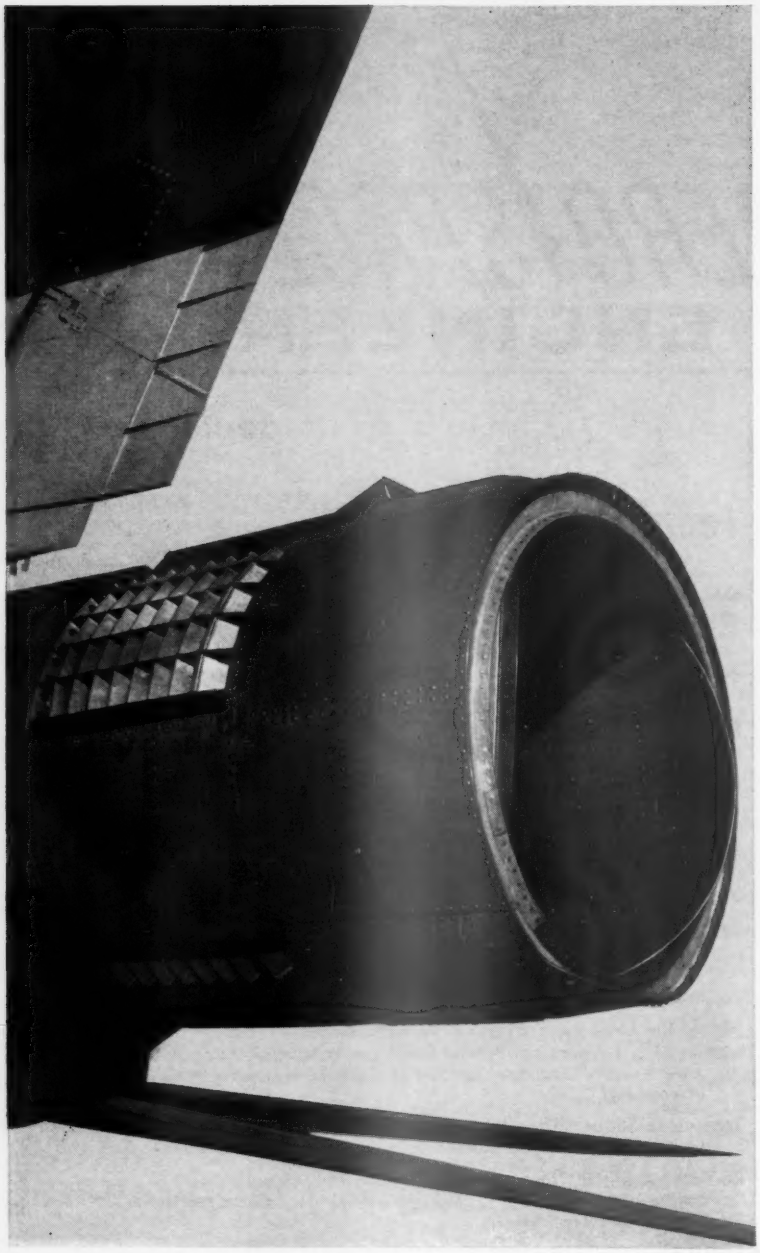


ROHR

designed and built F-100 THRUST REVERSER

allows full thrust for more control at slower speeds

With full test stand trials completed, Rohr's fighter aircraft thrust reverser units are now undergoing flight tests by North American. This modulating type reverser was designed to be an integral part of the glide path control system, and to reduce ground roll during landing operations. The added safety of full thrust at slowed landing speeds and other in-flight aids are apparent.

Rohr engineers, with heavy experience in the field of thrust reversers, carried full responsibility from initial concept to working prototypes.

WORLD'S LARGEST PRODUCER
OF COMPONENTS FOR FLIGHT

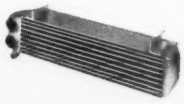
ROHR
AIRCRAFT CORPORATION

CHULA VISTA AND RIVERSIDE, CALIFORNIA

Harrison Oil Coolers...

HALT HEAT ON THE HILLER

General Motors Controls Temperatures on New Lycoming-Powered Hiller Helicopter!



Harrison aircraft oil coolers—another quality product of General Motors research.

From take-off to touch-down . . . this versatile new Hiller 12E takes over, whether it's toting tons of cargo or on traffic control. And Harrison takes over the vital engine-oil cooling job! This hard-working 'copter, powered by the new Lycoming VO 540 engine, can carry 65 percent more payload 50 miles farther than its commercial predecessor. This takes cool power . . . *and plenty of it!* Harrison takes these strenuous temperature-control assignments in stride. Backed by nearly a half century of experience in the engineering, research and manufacture of top-quality heat-transfer products, Harrison heat exchangers are found on every type of aircraft from civilian planes to intercontinental jets. If you have a cooling problem, look to Harrison for the answer.

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TEMPERATURES MADE TO ORDER

AIRCRAFT, AUTOMOTIVE, MARINE AND INDUSTRIAL HEAT EXCHANGERS

HARRISON RADIATOR DIVISION, GENERAL MOTORS CORPORATION, LOCKPORT, NEW YORK

XUM

TRW

Tapco develops test-proved

Titanium rocket

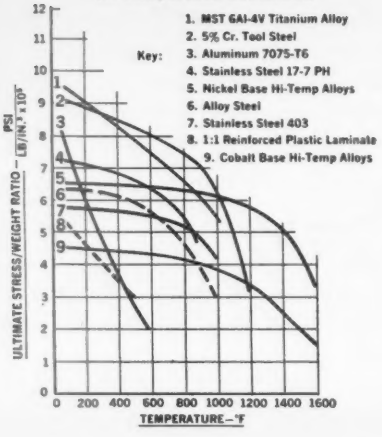
with guaranteed tensile

Sub-scale rocket motor hydrotest case, 20-inch diameter, fabricated from Mallory-Sharon 6Al-4V titanium alloy by the Tapco Group. Exhaustive tests permit Tapco to guarantee strength/weight ratios of 960,000.

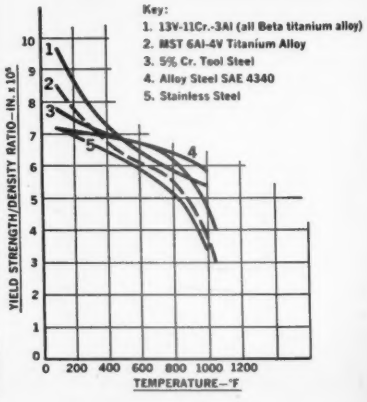
Titanium tops in Tapco Group's Tests

(Test data courtesy of Thompson Ramo Wooldridge)

VARIATION OF ULTIMATE STRENGTH/WEIGHT RATIO WITH TEMPERATURE (of comparable ductilities)


Key:
1. MST 6Al-4V Titanium Alloy
2. 5% Cr. Tool Steel
3. Aluminum 7075-T6
4. Stainless Steel 17-7 PH
5. Nickel Base Hi-Temp Alloys
6. Alloy Steel
7. Stainless Steel 403
8. 1:1 Reinforced Plastic Laminate
9. Cobalt Base Hi-Temp Alloys
ULTIMATE STRESS/WEIGHT RATIO — PSI / LB/IN.³ x 10⁵
0 1 2 3 4 5 6 7 8 9 10 11 12
0 200 400 600 800 1000 1200 1400 1600
TEMPERATURE—°F

APPROXIMATE VARIATION OF YIELD STRENGTH/DENSITY RATIO WITH TEMPERATURE


Key:
1. 13V-11Cr.-3Al (all Beta titanium alloy)
2. MST 6Al-4V Titanium Alloy
3. 5% Cr. Tool Steel
4. Alloy Steel SAE 4340
5. Stainless Steel
YIELD STRENGTH/DENSITY RATIO—IN. x 10⁵
0 1 2 3 4 5 6 7 8 9 10
0 200 400 600 800 1000 1200
TEMPERATURE—°F

motor case

strength/weight ratio of 960,000

Ring rolled cylinder and formed dome of Mallory-Sharon 6Al-4V titanium alloy.

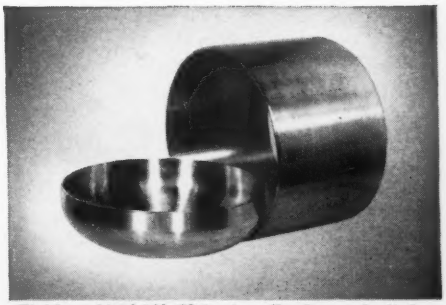
New, advanced type, solid-fuel propellants . . . plus the need to achieve maximum range . . . demand an entirely new look at tensile strength/weight ratios in missile components. For example, designers can no longer tolerate rocket cases whose inert mass approximates 20% of total unit weight. Today's goal: hold rocket-case weight to *less than 10%* of propellant weight.

To achieve this goal, tensile strength/weight ratios of close to 1,000,000 are required in the rocket case. In this range, welded heat-treated steels develop severe embrittlement and high notch sensitivity when subjected to rocket case hoop stresses — largely ruling out their use. Titanium overcomes these disadvantages, plus giving *a weight saving of 25% to 38% over the best competitive steels!*

Extensive development work and testing by the Tapco Group of Thompson Ramo Wooldridge has conclusively proved Mallory-Sharon 6Al-4V titanium alloy to be the most suitable material for this application (see charts at left). It provides the necessary strength and ductility without embrittlement or distortion. It can be readily welded and age hardened to give the welded strength/weight levels required. In view of titanium's outstanding advantages and continuous reductions in cost, any price difference becomes insignificant.

Thompson's excellent experience with MST 6Al-4V titanium alloy enables this leading component parts producer to *guarantee* performance and strength ratios of its titanium rocket motor cases . . . in sizes up to 60″ diameters, 20-ft. lengths.

Here's important proof of titanium's growing advantages in missile applications . . . and of Mallory-Sharon's ability to furnish material to meet the most exacting quality specifications. For technical information or application assistance write to: Aircraft & Missile Development Dept., Mallory-Sharon Metals Corporation, Niles, Ohio.



Finish machined 6Al-4V titanium alloy dome and cylinder.

Tungsten arc inert gas welding of titanium dome to cylinder (final pass).

MALLORY MS **SHARON**

MALLORY-SHARON METALS CORPORATION • NILES, OHIO

Integrated producer of Titanium • Zirconium • Special Metals

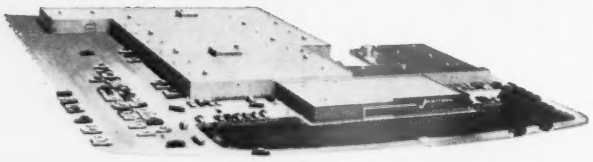
167 Operations to Reliability

The machine operator in the foreground is chamfering a bore—the 37th operation on a Janitrol pneumatic control body. He works routinely to ±.0001" and has the mental flexibility to adapt to rapid design changes. He's been machining aircraft pneumatic parts for many years and has a deep respect for precision as an essential factor in reliability.

Janitrol people—whether designing heat exchangers, testing pneumatic controls, or fabricating high performance duct couplings—know that sudden design change is part of the means to reliability. They can handle it.

When your advanced missile and aircraft designs demand imaginative and knowledgeable sub-system management, and when you need a proposal for air supply systems, controls, heat exchangers, duct couplings and supports, or combustion systems for aircraft and ground support, call on your Janitrol Engineering Representative. *Janitrol Aircraft Division, Surface Combustion Corporation, 4200 Surface Road, Columbus 4, Ohio.*

pneumatic controls • duct couplings and supports • heat exchangers • combustion equipment for aircraft, missiles, ground support



JANITROL

Write for "Janitrol Resources," brochure on Janitrol capabilities.

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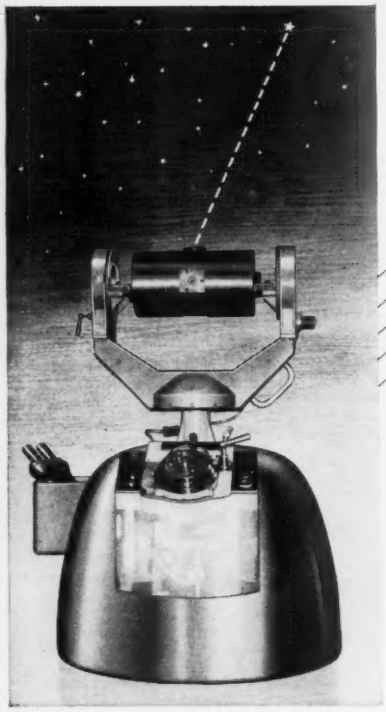
ore you cut tin—
call Shafer in
The earlier you count on Shafer Bearing performance in advanced designs, the surer you'll be of successful missile control systems at final count-down.
High temperatures...high loads...thermal shock...all these are familiar problems to missile designers and to Shafer engineers, for Shafer has pioneered in the research and development of high temperature control bearings for missiles of advanced design and proven capability.
The famous exclusive design features that have made Shafer first choice for the toughest bearing applications in the airframe industry—greater capacity for its envelope dimensions and weight...integral self-alignment with full capacity...greater resistance to shock loadings and vibrations—may provide the answer to your missile control system bearing problems.
So before you cut tin, be sure to call Shafer in.
Shafer Bearing Division, CHAIN Belt Company,
Downers Grove, Illinois.
SHAFER® BEARINGS
CHAIN BELT COMPANY



Do you need

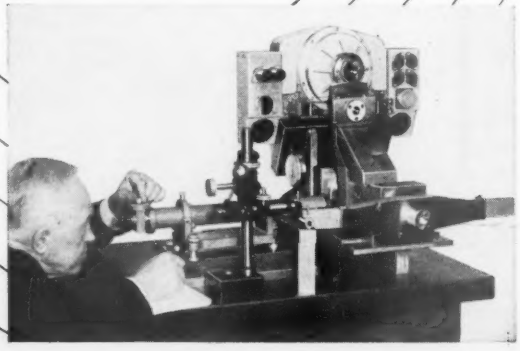
EXTREMELY ACCURATE TEST STANDS FOR Inertial Guidance Systems?

see VINCO

Precision has been Vinco's most important product for more than thirty years. The ability to work to extremely close tolerances is an indispensable asset to the missile manufacturer requiring Gyro System Test Stands.

Vinco manufacturers extremely accurate test stands complete with gearboxes. These gearboxes isolate the Gyro System from the effect of the earth's rotation. Vinco invites you to submit your guided missile test stand problems.

Inspection of a Vinco Sidereal Gearbox by an autocollimator and polygon reflector segment. Output accuracy limit of complete gear train is 3.6 seconds of arc; gear ratio 2,584,800 - 1.



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Johns-Manville announces new **MIN-KLAD** Insulation!

This one new product answers 4 basic thermal and mechanical requirements
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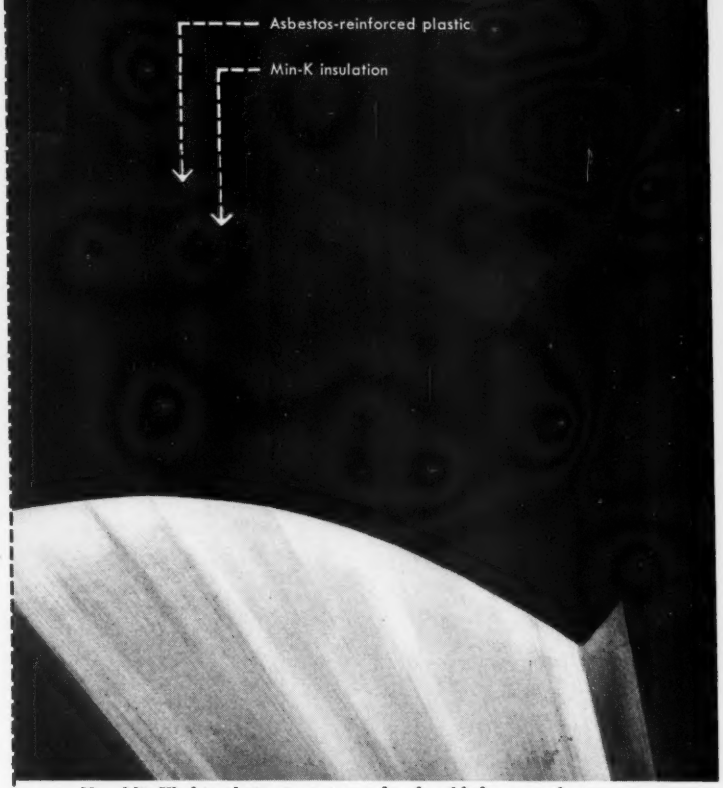
high heat capacity plus erosion resistance
high strength



New Min-Klad insulation is engineered and molded to your design requirements.

Combines the capabilities of asbestos-reinforced plastic with the dramatically low conductivity of MIN-K insulation!

New Min-Klad insulation may well be the most significant advance ever made in missile and rocket insulation.

Developed by Johns-Manville research scientists, Min-Klad is the only product of its kind, a permanent lamination of the missile industry's two most effective high-temperature materials: 1) reinforced plastic and 2) J-M's recently developed Min-K insulation.

Does more than plastic alone

Min-Klad gives the missile designer all the advantages of high-temperature plastic: Strength, toughness, rigidity! Erosion resistance! High heat capacity! Yet Min-Klad does more.

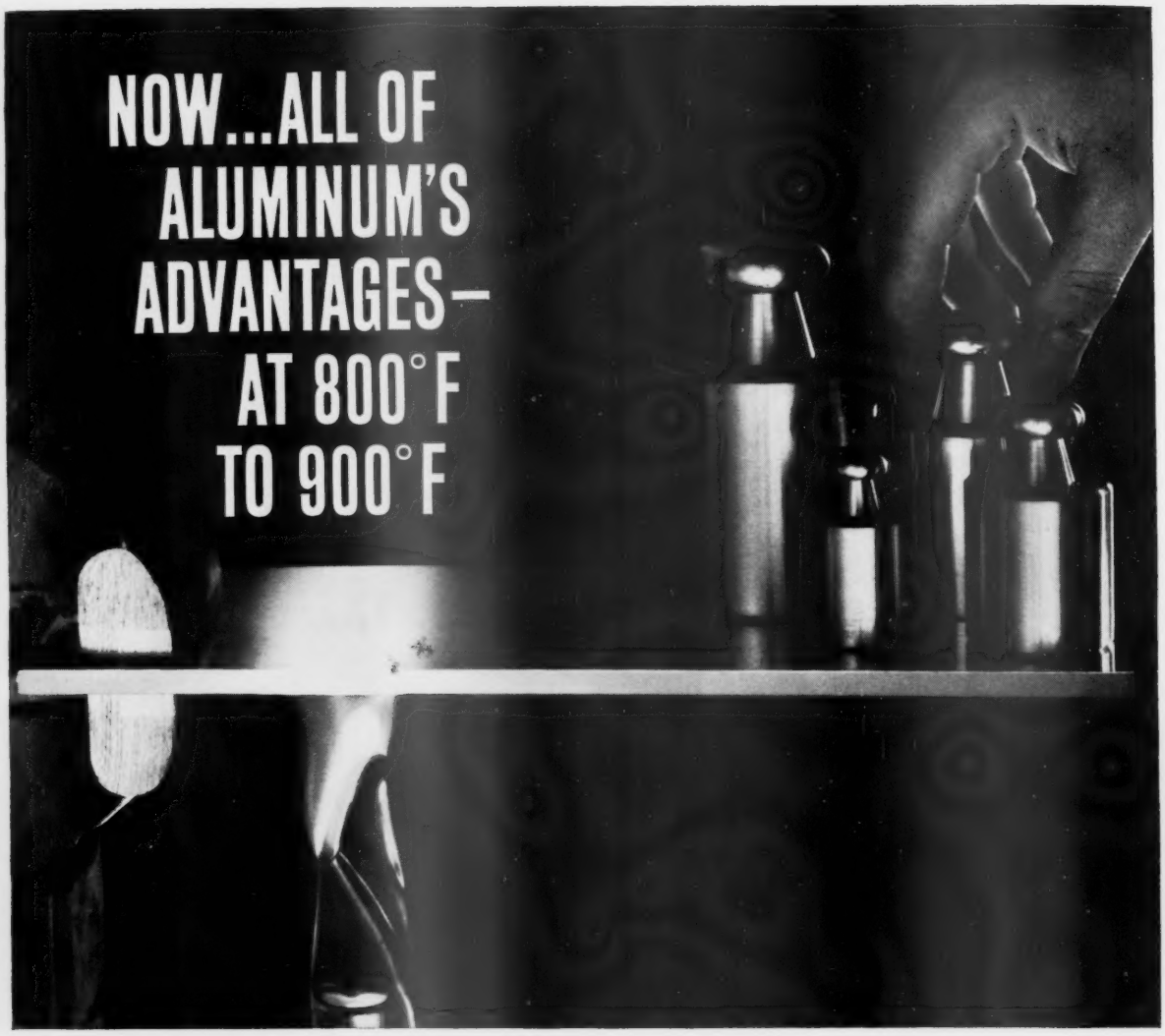
It also insulates . . . and with dramatic effectiveness! Its insulating element is J-M's Min-K, an insulation with thermal conductivity that is actually lower than the molecular conductivity of still air. And this conductivity (already less than half that of the best fibrous insulations) drops still further with altitude. At 10 miles, for example, it is decreased by as much as 40%, with further decreases at greater altitudes.

Wide range of applications

Min-Klad offers the missile and rocket designer a rich choice of heat-control possibilities. It may be used for a part that must insulate, yet have the structural advantages of plastic. Where requirements call for a scuff- and erosion-resistant insulating surface . . . or for a good adhesive bond between Min-K insulation and other surfaces. Or, it may be used to control high transient temperatures! For high heat capacity of asbestos-reinforced plastic combined with the low conductivity and heat capacity of Min-K result in a product that provides minimum heat transfer under transient conditions.

Min-Klad is now being tested for approximately two dozen missile and rocket designs. Why not investigate this new material for your present thermal requirements? Upon request, we'll be pleased to send you a sample of the material along with detailed technical information. Write Johns-Manville, Box 14, New York 16, New York. (Ask, too, for information on Min-K insulation and the new aviation insulation brochure IN-185A.) In Canada: Port Credit, Ontario.

JOHNS-MANVILLE JM PRODUCTS



New Aluminum Powder Metallurgy Products Open New Application Horizons

THE TRADITIONAL advantages of aluminum—at temperatures up to around 500° F—can now be extended to temperatures hundreds of degrees higher than conventional aluminum can take.

THANKS TO Alcoa's pioneering with the metallurgical technique known as "dispersion hardening," solid aluminum products reformed from *powdered* aluminum by heat and pressure take on new qualities. They are fine-grained, hard, tough, sapphire-like in brilliance, and amazingly resistant to heat effects.

ALUMINUM POWDER metallurgy products—"APMP" for short—are available in a family of four alloys. They are usually extruded into forms which can subsequently be further extruded, rolled, forged, drawn or impacted by conventional metal-working methods. Where you need the properties of aluminum, but where temperatures seem "too high" for conventional aluminum products, chances are that one of these four alloys may solve a host of hectic problems.

NATURALLY, there's more to the story than we've been able to pack into this limited space. If you'd like to know more, please write for our free booklet, *Alcoa's Aluminum Powder Metallurgy (APM) Alloys.* Aluminum Company of America, 2028-J Alcoa Building, Pittsburgh 19, Pennsylvania.

Your Guide to the Best in Aluminum Value

ALCOA ALUMINUM

For exciting drama watch "Alcoa Presents" every Tuesday, ABC-TV, and the Emmy Award winning "Alcoa Theatre" alternate Mondays, NBC-TV

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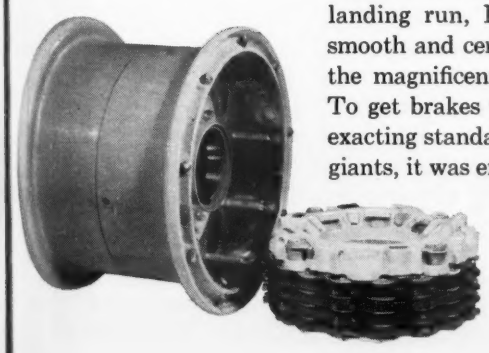
JETLINERS DEMAND JET-AGE BRAKES



From touch-down to the end of the landing run, Bendix brakes provide smooth and certain ground control for the magnificent new jet airliners . . . To get brakes that measure up to the exacting standards of these swept wing giants, it was entirely logical to look to the world's most experienced supplier . . . For similar reasons, Bendix brakes are regular equipment on the largest and fastest military jets, as well as fully certified by FAA for the new civilian jets . . . BRAKES BY BENDIX is another important reason why you can fly the jetliners with complete assurance.

Bendix PRODUCTS DIVISION South Bend, IND.

Bendix
AVIATION CORPORATION

BASIC REQUIREMENTS

for outer space

The space/missile era has made it essential for today's components and systems to function precisely in environments that are literally out-of-this-world. Such stringent requirements can only be met by companies long experienced in component design and with proved records of imaginative engineering. Kearfott, long the leader in servo component design and production, has consistently looked into the future to anticipate the increased performance characteristics missile components must supply. As a result, it has not only developed an entirely new generation of precision components but established the ability to create radically new concepts in sensors and control elements.

THE PROBLEM: **HIGH ACCURACY**
THE SOLUTION: Synchros with maximum error from electrical zero of 20 seconds. Tachometers with linearity .05% over the speed and temperature range.

THE PROBLEM: **HIGH AND LOW TEMPERATURE**
THE SOLUTION: Servomotors, synchros and tachometers are now available for the temperature range of −54° C to 200° C with new developments soon to increase the range to 400° C.

THE PROBLEM: **RADIATION RESISTANCE**
THE SOLUTION: Kearfott servomotors, synchros and tachometers operate at 200° C and can withstand radiation of 10^8 through 10^{10} roentgens.

THE PROBLEM: **SHOCK AND VIBRATION**
THE SOLUTION: All Kearfott components can be supplied to function as required during or after 20 g's shock or 2000 cps vibration.

THE PROBLEM: **MINIATURIZATION**
THE SOLUTION: Size 5 synchros and servomotors. Size 8 components are outstanding examples of Kearfott's ability to combine miniaturization with precise performance.

THE PROBLEM: **LONG LIFE**
THE SOLUTION: Components are being developed which will operate continuously for 12 months in a total vacuum, the environment of outer space.

Representative of Kearfott's ability to look ahead are such current areas of development as Solid State Transducers and Control System Components. **You can take advantage of Kearfott's long-established know how in developing precision components for today — and tomorrow — by writing for details concerning your specific requirements.**

Engineers: Kearfott offers challenging opportunities in advanced component and system development.

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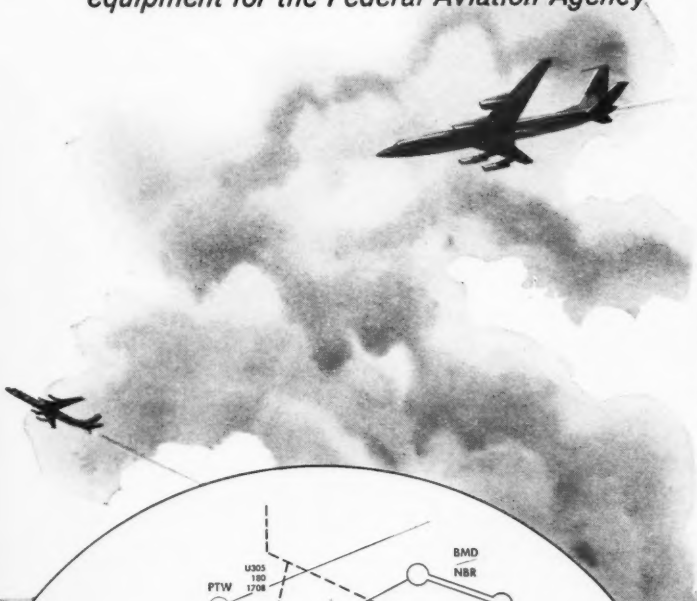
GPL data handling

equipment for the Federal Aviation Agency

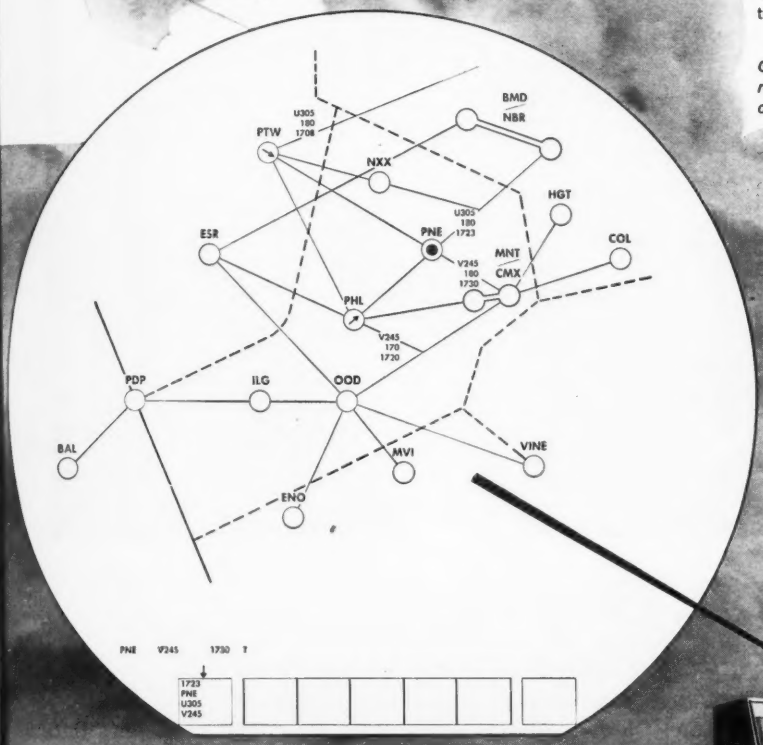


GPL's experience and ingenuity are at work assisting the FAA Bureau of Research and Development in the creation of a modern data processing central, the heart of tomorrow's air traffic control system. The central will receive up to 400 aircraft flight plans hourly, "remember" 1,000 such plans simultaneously and transmit 200 plans and 800 updates hourly to adjacent centers. Automatic processing and unique displays of such data will make significant contributions to the efficient control of aircraft in en-route, transition and terminal areas.

The FAA data processing central is just one of a number of airborne and ground-based programs reflecting GPL's capabilities in the data handling field. These programs are supported by GPL's proven ability to understand the customer's problem and capacity to anticipate future requirements. The GPL organization is "systems oriented," offers complete capabilities ranging from research, engineering and manufacturing to customer service.

Why not put these broad capabilities to work on your problem?

GPL Avionic Division/airborne navigators/missile guidance/ radar/airborne computers/data handling systems/ communications equipment/infra-red/closed-circuit TV.



- AIRCRAFT—COMMERCIAL PRIVATE, MILITARY
- ADC, SAGE, SAC
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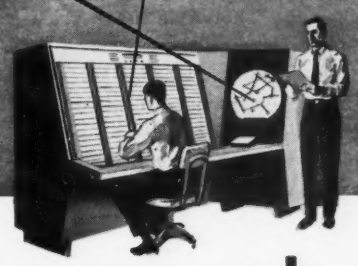
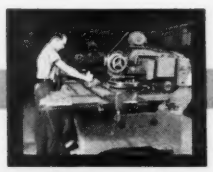
- WEATHER BUREAU
- AIRLINE DISPATCH (RADIO) OFFICES
- CAA TOWERS
- AIR TRAFFIC COMMUNICATIONS STATIONS (ATCS)
- ADJACENT ARTCCS

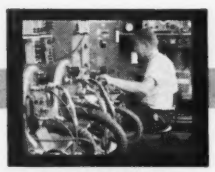


ENGINEERS — GPL achievements have opened some unusual research and development opportunities. Send resume to Personnel Director.

ENGINEERING



MANUFACTURING



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C. D. Boyce

October 1958, when the Thor-Able lunar probe soared 79,000 miles, was a time of quiet pride for Clay Boyce. Design engineer Boyce was responsible for successfully predicting the in-flight performance of the Aerojet second stage of the Able vehicle.

Clay Boyce has gone on to become an Aerojet Systems Division group leader, in charge of design and installation for the next generation of Able upper-stage vehicles for scientific and military applications. You'll agree, a mighty important assignment for a BSME still in his twenties.

Clay Boyce, with Aerojet since 1955, exemplifies the possibilities that exist at Aerojet for professionally gifted younger men to perform tasks of engrossing interest. We'd be delighted to hear from *you*. Write: Director of Scientific and Engineering Personnel, Box 296B, Azusa, California, or Box 1947B, Sacramento, California.

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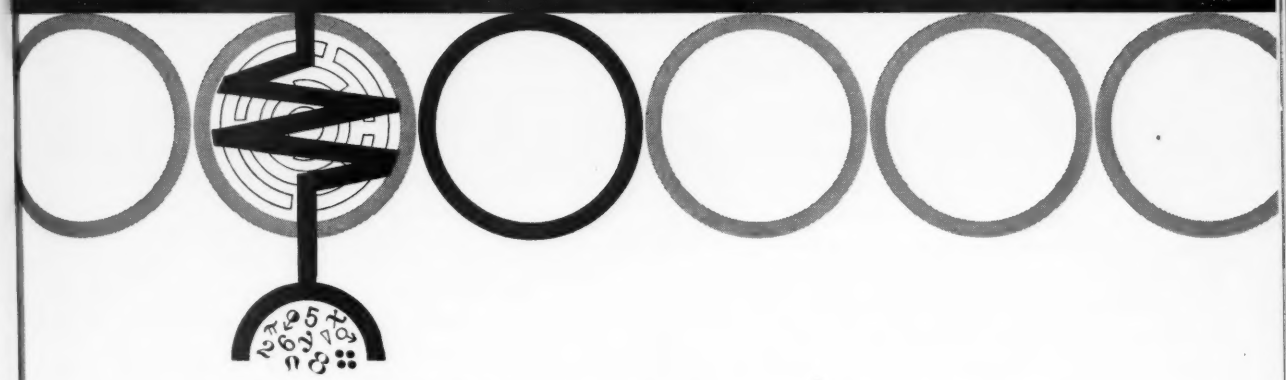

COMPUTATION ATTUNED TO TEAMWORK

IT TAKES A LOT OF PUSH IN THE RIGHT PLACES TO PUT A PROGRAM INTO SPACE. BURROUGHS CORP(RATION CONCENTRATES ON COMPUTATION—EVERY PHASE FROM BASIC RESEARCH THROUG PRODUCTION TO FIELD SERVICE. APPLY IT TO A TEAM AND THINGS HAPPEN. FOR BURROUGH CORPORATION HAS THE PROVED COMPETENCE TO MAINTAIN THE INTERFACING RELATIONSHIPS AN INTERTEAM COMMUNICATIONS THAT ACHIEVE SPACE OBJECTIVES COMPATIBLY AND EFFICIENTLY.

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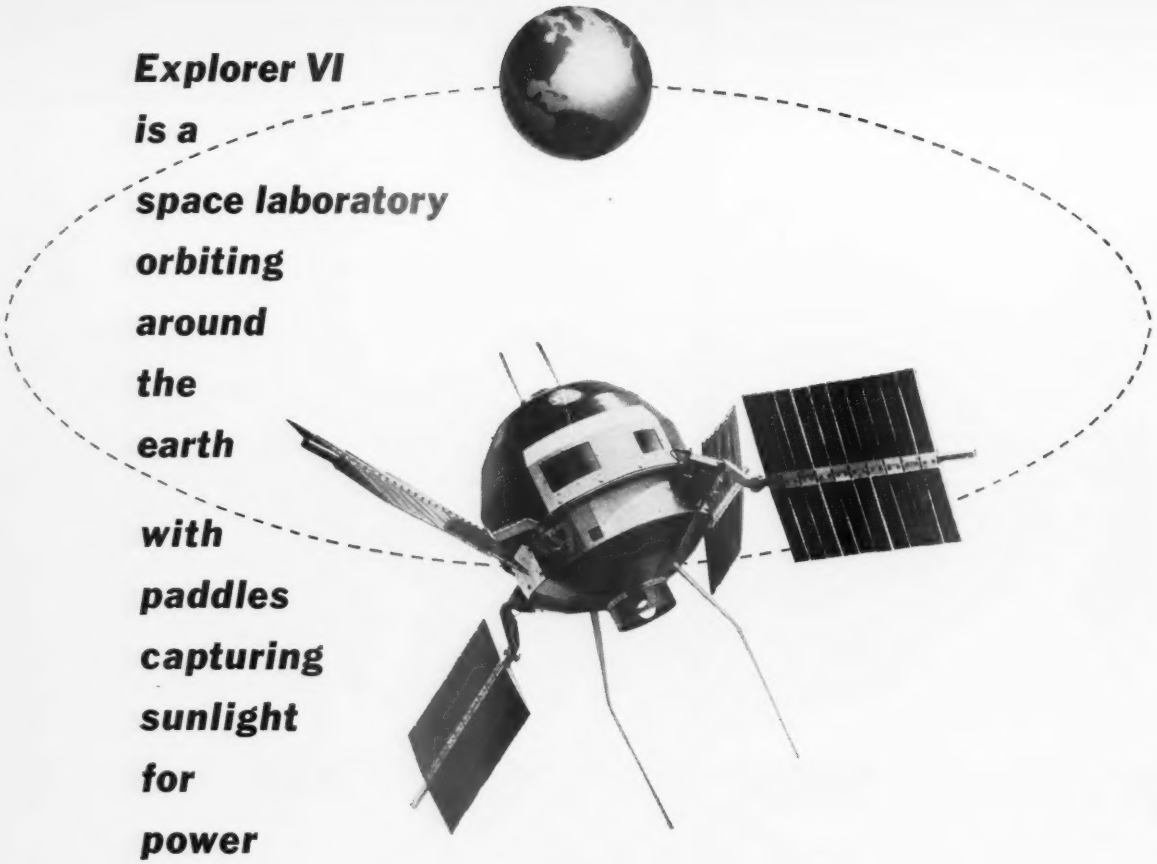
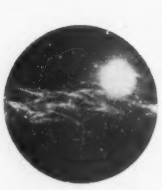
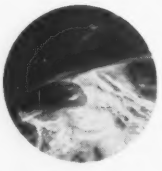
"NEW DIMENSIONS | in computation for military systems"

Explorer VI is a space laboratory orbiting around the earth with paddles capturing sunlight for power



The scientific data that will some day enable us to probe successfully to the very fringes of the universe is being recorded and transmitted at this moment by the space laboratory Explorer VI, a satellite now in orbit around the earth ● This project, carried out by Space Technology Laboratories for the National Aeronautics and Space Administration under the direction of the Air Force Ballistic Missile Division, will advance man's knowledge of: *The earth and the solar system . . . The magnetic field strengths in space . . . The cosmic ray intensities away from earth . . . and, The micrometeorite density encountered in inter-planetary travel* ● Explorer VI is the most sensitive and unique achievement ever launched into space. The 29″ payload, STL designed and instrumented by STL in cooperation with the universities, will remain "vocal" for its anticipated one year life.





How? Because Explorer VI's 132 pounds of electronic components are powered by storage batteries kept charged by the impingement of solar radiation on 8,000 cells in the four sails or paddles equivalent to 12.2 square feet in area ● Many more of the scientific and technological miracles of Explorer VI will be reported to the world as it continues its epic flight. The STL technical staff brings to this space research the same talents which have provided systems engineering and over-all direction since 1954 to the Air Force Missile Programs including Atlas, Thor, Titan, Minuteman, and the Pioneer I space probe.

Important staff positions in connection with these activities are now available for scientists and engineers with outstanding capabilities in propulsion, electronics, thermodynamics, aerodynamics, structures, astrophysics, computer technology, and other related fields and disciplines.

Inquiries and resumes are invited.

Space Technology Laboratories, Inc.

P. O. Box 95004
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Keep them Accurate . . .

General Radio Type 1429-A Fuel-Gage Tester checks the fuel-gage system in a typical commercial aircraft, an American Airlines' Boeing 707 Jet Flagship.

In use, the Tester's precision capacitors simulate the capacitive sensing elements in the aircraft's fuel tanks. The Tester dials are set to the known capacitance of the tank elements for a given quantity of fuel. The gage is then adjusted to indicate the simulated fuel quantity correctly.

. . . with the New Type 1429-A Tester for capacitance-type aircraft fuel gages.

Military designation is TTU-68/E (fulfills same function as military Type MD-1 or former General Radio Type P-579 Tester).

- ★ Can be used for calibrating fuel gages in either jet or propeller-driven aircraft.
- ★ Incorporates compensating capacitors to correct for dielectric variations in different types of jet fuels.
- ★ Smaller, lighter, and easier to read than previous models.
- ★ Militarized.

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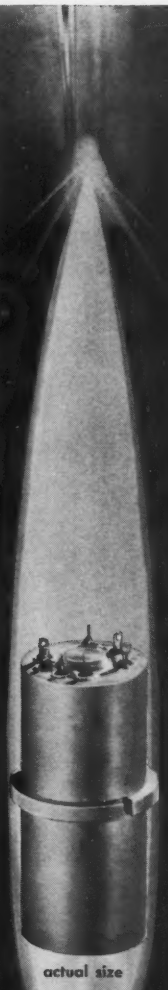
A unique combination of engineering and scientific skills, coupled with production ability . . . plus more than two decades of continuous development and production of newer and better airborne instruments – over 400,000 reliable guidance controls delivered – these are the reasons why Whittaker Gyro instruments are operational on many of the nation's major missile programs. From a simple gyro to complete stabilizing systems . . . Whittaker can provide the latest in design.



Check These Advantages In The New Whittaker Sub-Miniature Rate Gyro!

- reliable performance from – 65 F to 400 F
- only ¾ inch diameter – 2 inches long
- non floated – eliminates fluid expansion problems
- quick start – no heater necessary

For additional information on the Sub-Miniature Gyro – on any specialized control components or systems . . . write today for technical data.

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Free fall in relativistic space?

A complex meson field?

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How is it related to binding energy?

Gravity is both a bane and a boon to man's efforts—and a thorough understanding of it is of great significance in the completion of Allison's energy conversion mission.

Gravity conditions our thinking on advanced assignments. For example, in outer space there is a disorientation of conventional design. The fact that large accelerations can be obtained with low thrust forces has taken us into the new field of electrical propulsion, ion and magneto-hydrodynamic rockets.

In our inquiries, we supplement our own resources by calling on many talents and capabilities: General Motors Corporation, its Divisions, other individuals and organizations. By applying this systems engineering concept to new projects, we increase the effectiveness with which we accomplish our mission—exploring the needs of advanced propulsion and weapons systems.

Energy conversion is our business

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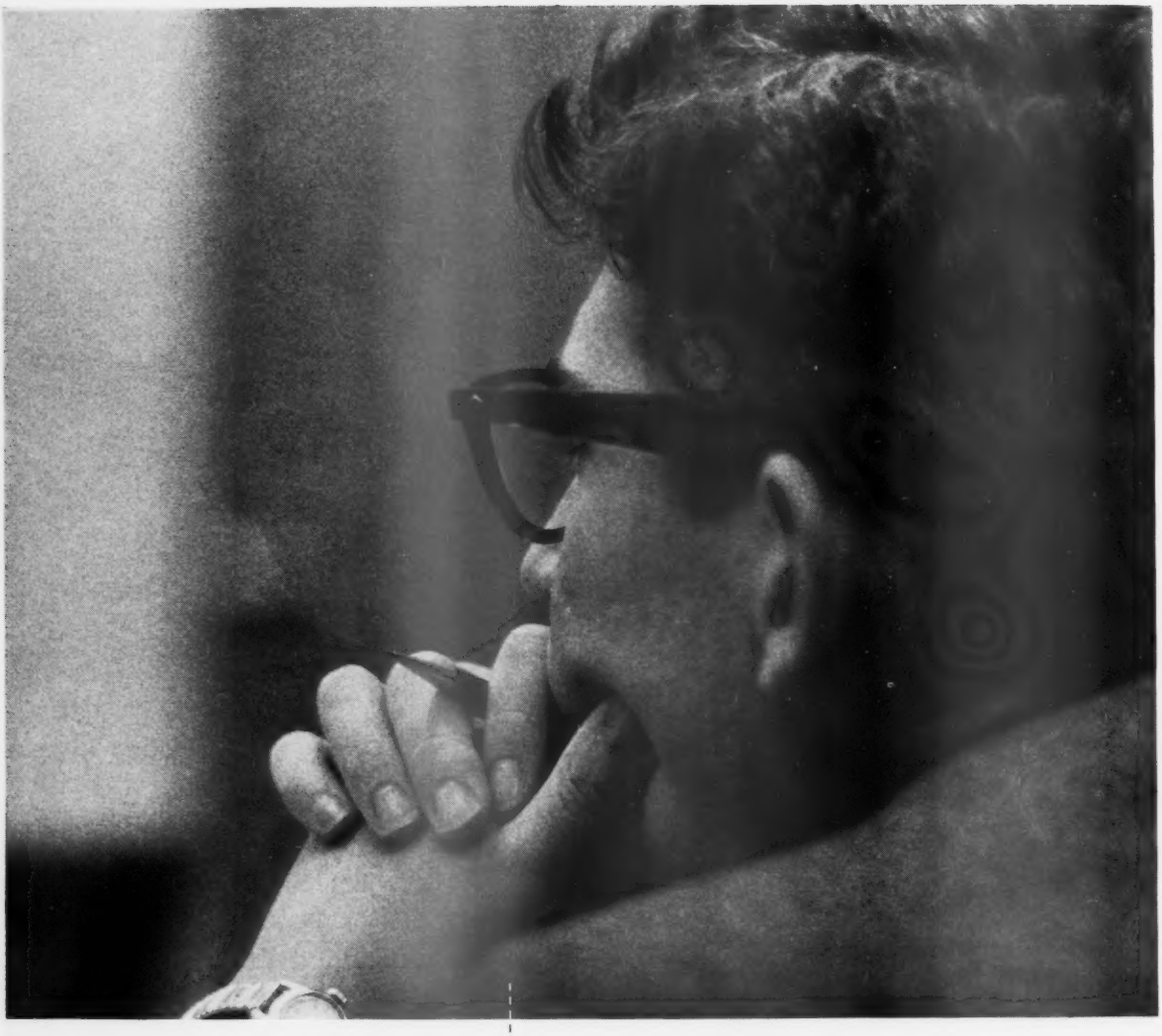

THE HUMAN FACTOR in today's technology

Scientists have long been preoccupied with the technological problems of Man and the Machine. The increasingly complex nature of advanced systems has created an urgent need to enhance man's contribution to effective systems performance. The complicated nature of this relationship requires the skills of psychologists, social scientists, mathematicians, and engineers.

At Ramo-Wooldridge, human engineering, personnel selection, individual and system training, display design, and communications are successfully integrated into systems design and development by the technique of large-scale simulation.

Simulated inputs enable scientists to observe a system as it operates in a controlled environment and make possible the collection of data on performance, training, human engineering, maintenance, and logistics and support. Scientists and engineers use this data to assure the design, production, and delivery of a unified system capable of high performance and reliability.

Expanding programs at Ramo-Wooldridge in the broad areas of electronic systems technology, computers, and data processing have created outstanding opportunities for scientists and engineers. *For further information concerning these opportunities write to* **Mr. D. L. Pyke.**

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IAS News

a record of people and events of interest to Institute Members

National Turbine-Powered Air Transportation Meeting to Be Held November 17–18

Preliminary Plans List Technical Sessions, Papers and Panel Discussions

Plans for the National Turbine-Powered Air Transportation Meeting are being built around the reporting of initial successes and problems with civil turbine-powered aircraft, as well as conclusions and recommendations in the immediate future. The meeting will be held at the Fairmont Hotel in San Francisco on November 17 and 18. General Chairman is Ray D. Kelly, Director of Technical Development Division, United Air Lines, Inc. Program Chairman is Stanley Moy, Chief of Component Overhaul, Pan American World Airways, Inc.

Technical Sessions

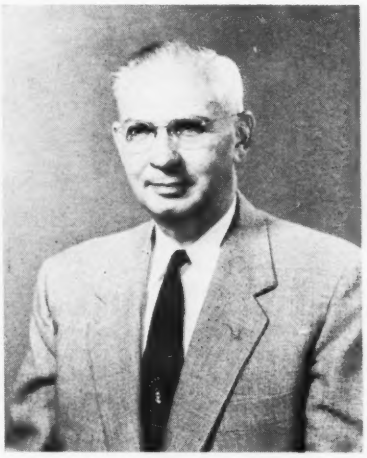
To date, three technical sessions have been planned. One session on "Airport and Ground Operation" will deal with the problems and requirements of airport design and ground handling and servicing of jet transports—towing, taxiing, refueling, loading, noise attenuation, reduction of exhaust blast and smell, safety precautions, and passenger handling at, to, and from airports.

Another session on "Aircraft Operations, Performance, and Maintenance" will cover the requirements, problems, and actual experience of turbine transport operation to date.

The third session scheduled—"The Future"—will evaluate types, the application, and the effect of the future higher-speed transports.

Technical Session Chairmen selected to date are Marvin Whitlock, Vice-President, Capital Airlines, and James Weesner, Division Operations Manager, Pan American World Airways.

A number of panel discussions will be held at the sessions. Panelists will be highly qualified airline management representatives. The range of subjects to be covered in the several papers presented will be airport design and ground handling, servicing and fueling, new turbine engines, aircraft flight operational characteristics and problems, traffic control, aircraft design criteria and maintenance, the next generation of transports, the local service aircraft's contribution to current and future needs, and the global aspects of air transportation.



Ray D. Kelly
General Chairman

Banquet Speaker

A banquet dinner will be held on the evening of November 17 at 7:00 p.m. The Speaker will be William A. Patterson, President of United Air Lines. IAS President William Littlewood, Vice-President—Equipment Research, American Airlines, Inc., will be Toastmaster. General Quesada's office of the FAA has agreed to provide a speaker for the luncheon to be held the same day.

Involved in plans for the meeting is the San Francisco Section whose Chairman is Robert Crane, Ames Research Center, NASA. Committees and their heads are: Housing and Meeting Accommodations—Norman R. Bergrun, Staff Head, Test System Analysis Department, Lockheed Aircraft Corporation. Transportation—Manley J. Hood, Technical Assistant to the Director, Ames Research Center, NASA. Finance—George Kenyon, Ames Research Center, NASA.

Program announcements giving complete details will be mailed to members.

Crowley Retires From NASA; Abbott Is His Successor

John W. Crowley, Jr. (F), Director of Aeronautical and Space Research for the NASA, retired from his post on June 30 after a 38-year career as a research scientist. Ira H. Abbott (F), who has been Deputy Director, was named successor.

At a dinner on June 30, marking Mr. Crowley's retirement from government service, he was awarded the NASA Distinguished Service Medal by T. Keith Glennan, NASA Administrator. The medal was accompanied by a citation signed by Dr. Glennan and Dr. Hugh L. Dryden, Deputy Administrator. The citation noted the outstanding part played by Mr. Crowley in accelerating "progress in American aircraft, missiles and spacecraft by scientific investigations, by developing young research scientists, by enlarging their vision and building their morale, and by promoting teamwork and cooperation with the military and industry."

Mr. Crowley received a B.S. degree in Mechanical Engineering from Massachusetts Institute of Technology in 1920, and joined the staff of the NACA the following year at the Langley Aeronautical Laboratory.

Translation of Leading Soviet Journal Becomes Available

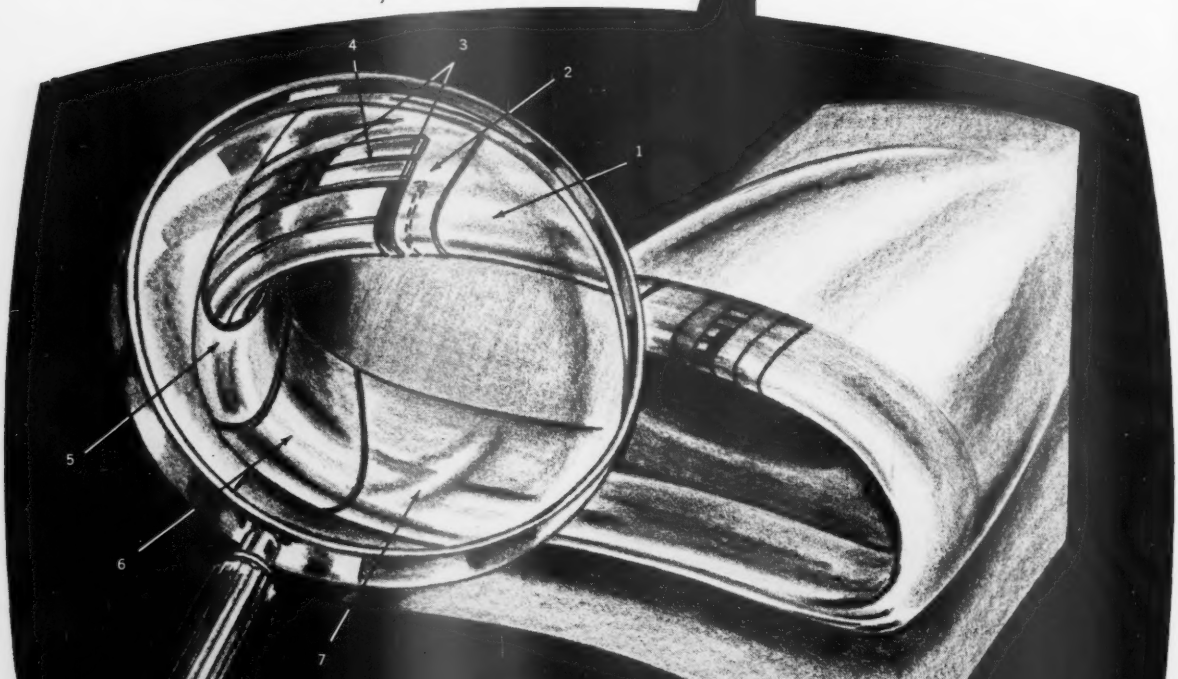
The leading Soviet periodical *Prikladnaia Matematika i Mekhanika* (Applied Mathematics and Mechanics), which is published bimonthly by the Institute of Mechanics, Division of Technical Sciences of the Soviet Academy of Sciences, is being translated and published as a regular journal by the Pergamon Institute for the American Society of Mechanical Engineers. The ASME, upon the initiative of its Applied Mechanics Division, has

(*Continued on page 26*)

napier SPRAYMAT

anti-icing/de-icing...

OVER
15,000,000 MILES
OF SERVICE



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3. COPPER BUSBARS
4. METAL HEATING ELEMENT
5. RESIN TOPCOAT
6. "STONEGUARD" LEADING EDGE PROTECTIVE RING
7. EROSION RESISTANT SURFACE COATING

After 9 years of development, testing and service, SPRAYMAT electrothermal ice elimination system has been enthusiastically accepted in the United States, and is in use on such aircraft as Lockheed's Electra and North American's Sabreliner, and was successfully tested on Lockheed's C-130A. SPRAYMAT has long been in use on such aircraft as the Britannia, Comet, Caravelle, Friendship, Vanguard, Viscount 810 and many others.

SPRAYMAT can be applied to *any* surface, of any material, however complex the curvature. Simple field repairability and aerodynamic and thermal efficiency assures its superiority to any existing system.

Basically, as shown in the above diagram, SPRAYMAT consists of, first, a base of insulating resin; next a layer of metallic heater element of a controlled, predetermined design pattern; and finally a mirror-finish coating of insulating resin. Under normal operating conditions, the service life of SPRAYMAT will exceed that of the aircraft structure itself!

Other applications for **SPRAYMAT** include:
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PacAero is SPRAYMAT's sole United States manufacturer and distributor. A call or letter will bring you into immediate contact with a well-informed SPRAYMAT sales-engineer to discuss the application of SPRAYMAT to your specific ice-protection problems.

Visit our Spraymat exhibit in booth 31 at the SAE Convention in Los Angeles.

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PACAERO

1,804 Registered at National Summer Meeting for New Record

Attendance Up 32 Per Cent Over Last Year; 84 Speakers Heard at Day and Night Technical Sessions

NINE months of planning for the Institute's National Summer Meeting toppled registration records June 16–19 as Los Angeles, Calif., welcomed 1,804 IAS members to 18 technical sessions, a field trip, and other events. Chairman of a NSM committee of 20, each of whom was assigned coordination tasks, was John R. McMaster (M), of Lockheed Aircraft Corporation.

The record registration exceeded last year's (1,366) by 32 per cent. Total attendance at the 18 technical sessions, six of which were classified, was about 6,241. Three luncheons drew a total attendance of 898, while 888 persons attended the banquet dance, which was a sell-out a month before it took place.

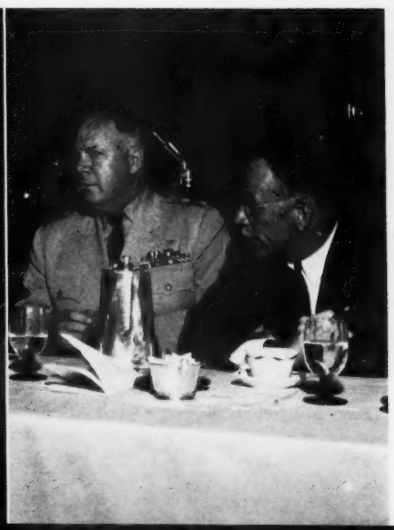
Eighty-four speakers appeared before the technical sessions, held during the mornings and afternoons of the 16th, 17th, and 18th, as well as at night on the 16th, 17th, and 19th. The field trip (see last month's AERO/SPACE ENGINEERING) was attended by 345.

Technical sessions were held in the Convention Center of Los Angeles's Ambassador Hotel, while the Cocoanut Grove accommodated the luncheons and banquet-dance. This latter event featured presentation of the 1959 Octave Chanute Award—"for a notable contribution made by a pilot to the aeronautical sciences"—to John P. Reeder, Chief, Flight Operations Branch, Flight Research Division, of NASA's Langley Research Center.

Out of 44 unclassified papers that could be made available to registrants prior to the meeting, 43 actually were obtainable as IAS Papers.

Committee members, with their company affiliations noted briefly, were:

J. G. Allen and P. H. Anderson, North American; R. E. Bateman, Boeing; L. F. Begin, Northrop; A. C. Brown, Wiancko; Ben Cagle, Southern Calif. Co-op. Wind Tunnel; C. R. Cantrell and J. S. Clauss, Lockheed; W. W. Dedon, Northrop; J. W. Ellinwood, Douglas; F. M. Friedlaender, Southern Calif. Co-op. Wind Tunnel; D. L. Kelly, Lockheed; Major F. G. Lester, USAF; E. B. MacCuish, Lockheed; E. O. Marriott, Hughes; S. W. Mikulka, General Electric; K. F. Nicholson, Douglas; Alexander Satin, J. H. Pomeroy; R. S. H. Toms, Wiancko; Col. G. M. Townsend, USAF.



MEETING PARTICIPANTS AND GUESTS

Seen in top photo are James H. Doolittle (HF), Chairman of the Board, Space Technology Labs.; Joseph V. Charyk (AF), Asst. Secretary of the Air Force for R&D (banquet speaker); and IAS Pres. William Littlewood (HF).

In center photo are Major Gen. John W. Sessums, Jr., USAF, Hq., ARDC, and Hall Hibbard (F), Senior V-P, and V-P—Engrg., Lockheed. Immediately above, Rear Adm. J. P. Monroe, USN, Comdr., Pacific Missile Range, converses with Arthur E. Raymond (HF), Senior V-P—Engrg., Douglas.

At far left are Peter Masefield (HF), Managing Dir., Bristol Aircraft (luncheon speaker), and John R. McMaster (A), Meeting Chairman. In photo immediately at left, Major Gen. S. T. Wray, USAF, Comdr., W-P AFB, is shown with Clark B. Millikan (HF), Dir., Guggenheim Aero. Lab. and Southern Calif. Co-op. Wind Tunnel.

XUM

IAS News (Cont. from page 23)

secured a grant-in-aid for this purpose from the National Science Foundation.

The ASME Advisory Committee on translations, headed by George Gerrmann of Columbia University, includes William Prager AFIAS, of Brown University and Leon Trilling of Massachusetts Institute of Technology, plus a panel of translators.

PMM contains papers in applied mathematics and in both solid and fluid mechanics, and is the recognized publication medium for Soviet scientists and engineers working in the fields of the aeronautical sciences, astronautics, rocketry, and space flight.

No. 1, Vol. 22, 1958, is the first publication in this new translation series. Issued bimonthly, the annual subscription rate is $35, and the magazine is available from Pergamon Press, 122 East 55th St., New York 22, N.Y.

Daniel J. Fink (AF), Chief Engineer of Allied Research Associates, Inc., a subsidiary of Vertol Aircraft Corp., has been elected a Vice-President of the firm.

IAS News — News of Members

Philip N. Anderson (M) has been named Assistant Manager of the Engineering Design Department, Vehicle Development Laboratory, Space Technology Laboratories, Inc. He was formerly Design Supervisor—Missiles.

Charles Z. Becker (M) has joined the staff of the West Coast Missile and Surface Radar Department, Radio Corporation of America, as Manager of Atlas ICBM contracts. He was formerly with Summers Gyroscope Co. as Sales Manager.

C. W. Chillson (AF) has taken a year's leave of absence from his position as Assistant Chief Engineer, Propeller Division, Curtiss-Wright Corp., to join the Advanced Research Projects Agency, Institute for Defense Analysis, Washington, D.C.

Gabriel C. Danch (M) has been named Manager of the Washington Office of U.S. Industries, Inc. He was formerly with Ryan Aeronautical Co. as Washington Representative.

Allan F. Donovan (AF), Vice-President and Director of Advanced Systems Planning, Space Technology Laboratories, Inc., has been named a delegate to a panel of technical experts which will advise the U.S. Committee on Nuclear Testing.

Dr. Walter R. Dornberger (AF) has been elected a Vice-President of the Bell Aircraft Corp. Dr. Dornberger is Director of Engineering for Bell's Niagara Frontier Division.

Dr. Morris Feigen (AF) has been appointed Manager of the Engineering Design Department of the Vehicle Development Laboratory, Space Technology Laboratories, Inc. Dr. Feigen has been a member of the Technical Staff since April, 1958.

James L. G. Fitz Patrick (A), Head of the Department of Mechanical Technology, Staten Island Community College, has been appointed first academic Dean of the college. He will serve as Dean of the Faculty and will act under the college president in administering the academic program.

Kenneth M. Foreman (A) has been named Principal Scientific Research Engineer, Plasma Propulsion Project, Republic Aviation Corp. He was formerly a Research Engineer, Engine Division, Fairchild Engine and Airplane Corp.

Lloyd Harris (M), formerly Chief Pilot of Lockheed Aircraft's Georgia Division, has joined the company's Sales Branch as Sales Representative in Europe and will establish headquarters in Paris.

Robert L. Hirsch (M) has been promoted from Assistant Manager to Manager of Aerojet-General Corp.'s Washington, D.C., office. He will be responsible for obtaining and analyzing the requirements of Washington customers at the policy level and coordinating this information with the management.

Paul M. Johnstone, Jr. (A), formerly Aerodynamics Design Engineer with Douglas Aircraft Co., has been named Operations Engineer for Hawaiian Airlines in Honolulu.

Prof. Boris V. Korvin-Kroukovsky (F) has retired from his full-time duties as Senior Scientist at the Davidson Laboratory of Stevens Institute of Technology. Prof. Korvin-Kroukovksy, who was also Research Professor of Fluid Dynamics, will continue as a Technical Consultant.

Lloyd G. Ludwig (M) has been appointed Staff Assistant to the Director of the Vehicle Development Laboratory, Space Technology Laboratories, Inc. He was formerly Head of the Electromechanical System Section, Guided Missile Research Division, Ramo-Wooldridge Corp.

John H. Meyer has re-entered the field of nuclear engineering with formation of the firm Atom Apply. Mr. Meyer will be General Manager; he was formerly Structures Manager at McDonnell Aircraft Corp.

Charles I. Morton (A), formerly Assistant Director of the Export Division of Curtiss-Wright Corp., has been appointed Manager of the Aviation Division of Smith, Kirkpatrick & Co., Inc., Exporters and Importers.

William A. Nash (AF), Professor of Mechanical Engineering, University of Florida, has been appointed to the Engineering Sciences Advisory Panel of the National Science Foundation, Washington, D.C.

Gerard E. Nistal (A), an Industrial Marketing Consultant, was appointed to the Summer School Faculty of Hofstra College, Hempstead, L.I., as Adjunct Assistant Professor of Marketing, School of Business.

Dr. William Prager (AF), Professor of Applied Mathematics and Chairman of the Physical Sciences Council at Brown University, has been honored by election to the Polish Academy of Sciences as a foreign member. He has also been named

Emerson W. Conlon (F) has been named Assistant Director of Aeronautical and Space Research (Power Plants) for NASA. He has taken a leave of absence as Director of Research for Drexel Institute of Technology to accept the appointment.

Necrology

Roy H. Murray

Roy H. Murray (A), who was Associate Professor and Acting Chief of the Department of Aeronautical Engineering at the University of Cincinnati, died on June 16.

Professor Murray was 36 years of age; he received a B.S. in Aeronautical Engineering from the University of Cincinnati in 1949 and did some of his postgraduate work at Ohio State University.

He was a member of the U.S. Naval Reserve and had been a naval pilot for 7 years.

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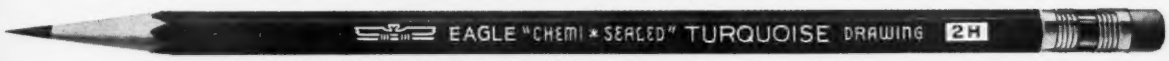

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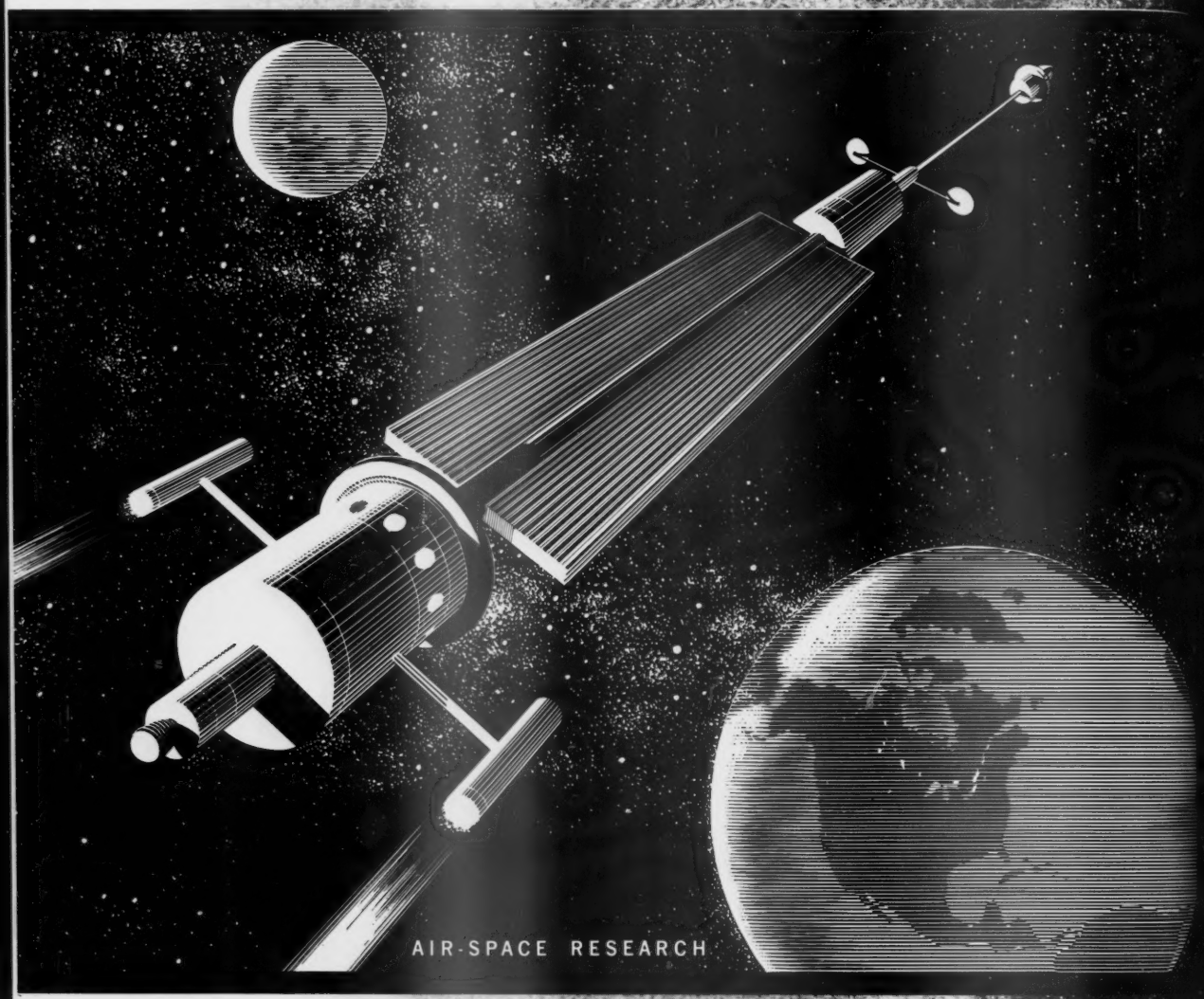
New Concepts for the Space Age
Mark 15 Years of Progress by MARQUARDT

When founded in 1944, Marquardt was an organization devoted exclusively to research and development of the ramjet propulsion principle. Today, in its fifteenth year, the Corporation employs more than 5,000 in the creation and exploration of new concepts for the space age. Marquardt is now diversified, operating in five basic areas—all primarily related to the search for earlier and ever more effective solutions to space-age problems.



NEW CONCEPTS IN AIR-SPACE RESEARCH spring from ASTRO—Marquardt's Air-Space Travel Research Organization—where studies of an ionic rocket capable of powering future space vehicles are in progress. Other imaginative ASTRO studies span a broad spectrum including high-energy fuels, exotic materials, nuclear powerplants, advanced optics, cryogenics, space medicine, communications and guidance.

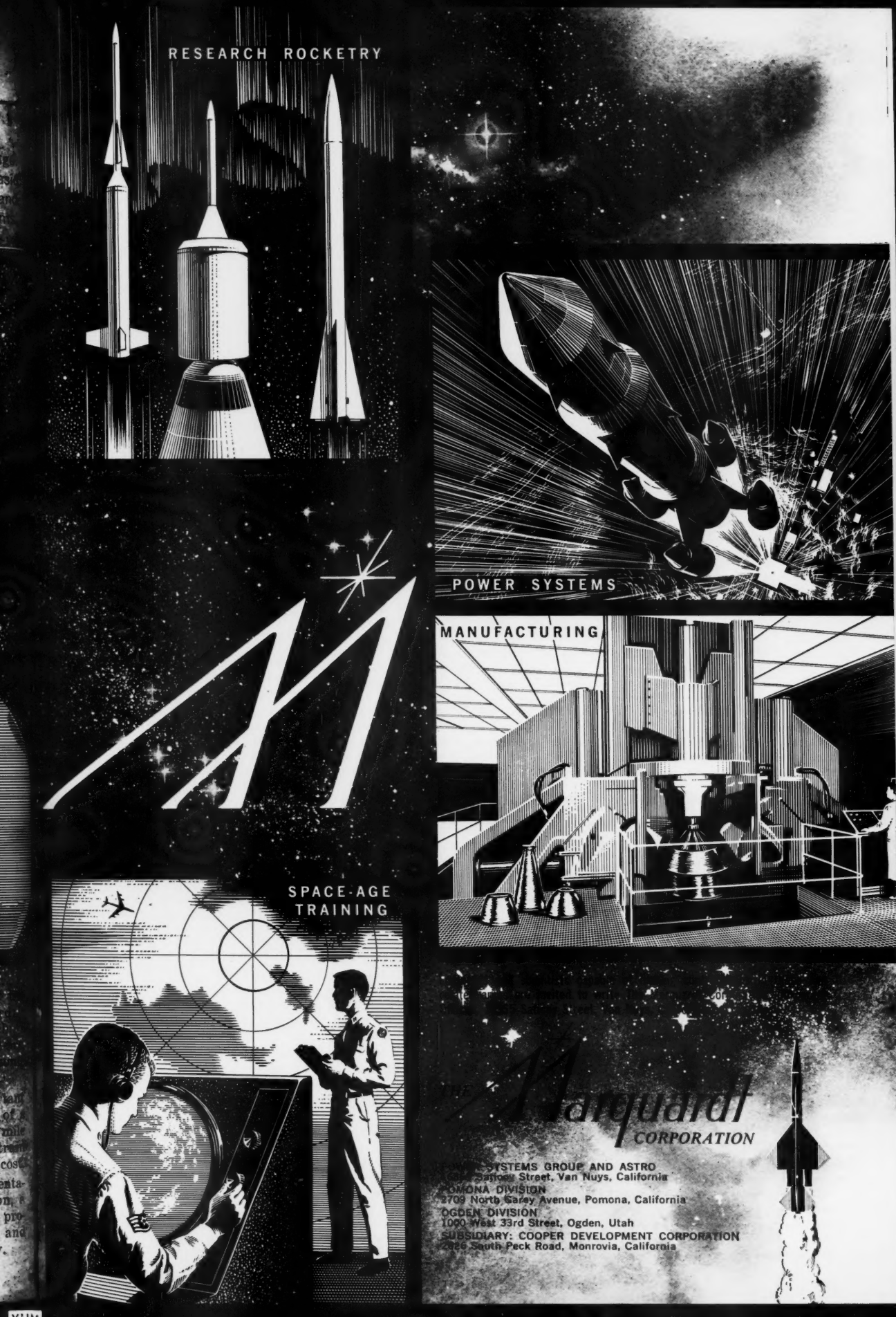
NEW CONCEPTS IN POWER SYSTEMS are in the making at Marquardt's Power Systems Group. Within the Group, Propulsion Division is engaged in continuing studies of a Hyperjet (rocket-ramjet) configuration capable of lifting future satellites from launch pad to upper atmosphere. Controls and Accessories Division is currently developing attitude controls for reconnaissance satellites, while Test Division is capable of ground-testing space-age hardware.

NEW CONCEPTS IN MANUFACTURING are exploited in the first-of-its-kind Hufford Spin-Forge at the Ogden Division. This 250-ton machine will contribute advances in space-age metal working [illegible] while augmenting the Division's production of ramjet engines for the Boeing Bomarc IM-99.

NEW CONCEPTS IN SPACE-AGE TRAINING are an important product of Marquardt's Pomona Division—creators of a unique system which realistically simulates a 4,000 mile mission on an 8-foot map. The system will ground-train air and spacemen without risk and at great savings in cost.

NEW CONCEPTS IN RESEARCH ROCKETRY and instrumentation come from Cooper Development Corporation, a Marquardt subsidiary. Cooper has contributed to programs including Explorer and Sunflare projects, and its Falling Sphere—is now at work on Project Mercury.

XUM


RESEARCH ROCKETRY
POWER SYSTEMS
MANUFACTURING
SPACE-AGE
TRAINING
Marquardt
CORPORATION
SYSTEMS GROUP AND ASTRO
Saticoy Street, Van Nuys, California
POMONA DIVISION
2709 North Garey Avenue, Pomona, California
OGDEN DIVISION
1000 West 33rd Street, Ogden, Utah
SUBSIDIARY: COOPER DEVELOPMENT CORPORATION
2826 South Peck Road, Monrovia, California

one of four foreign editors for one of the Academy's journals.

Dr. F. W. Reichelderfer (F, HM), Chief of the U.S. Weather Bureau, was presented with a certificate of Honorary Membership in the Society of Airway Pioneers for his outstanding achievements in furnishing weather services for all flying activities.

Carl L. Sadler (M), formerly Vice-President and General Manager of Sundstrand Aviation, will head the three Sundstrand divisions comprising the Aviation and Defense Products Group—Sunstrand Aviation, Sunstrand Denver, and Sundstrand Turbo.

George Schairer (F), who is Director of Research at Boeing Airplane Co., has been elected a company Vice-President.

Clarence A. Shoop (M) who is Vice-President and Director of Product Reliability and Flight Test, Hughes Aircraft Co., has been named, in addition to his present post, Manager of the company's International Division, responsible for activities outside the United States.

Ernest G. Stout (F) has been made Manager of Washington Operations for the Ralph M. Parsons Co. He was formerly Assistant Manager.

T. Paul Torda (AF) has become associated with the Armour Research Foundation of the Illinois Institute of Technology, Chicago, as Director of Research for Propulsion and Fluid Mechanics. He was formerly Professor of Mechanical Engineering, Polytechnic Institute of Brooklyn.

T. F. Walkowicz (AF), associate of Laurance S. Rockefeller, has been elected to the Board of Directors of Allied Research Associates, Inc., a subsidiary of Vertol Aircraft Corp.

IAS News — Corporate Member News

• **AC Spark Plug,** General Motors Corp., has appointed Kenneth H. Bender as Divisional Comptroller.

• **Aerojet-General Corp.** has announced plans for using the facilities at Downey and Riverside, Calif., formerly comprising the Rheem Manufacturing Co.'s Defense and Technical Products Division which was acquired by purchase recently. The new facilities will enable the carrying on of major Army programs. A Space Technology Division has been established to strengthen the company's position for assuming a larger role in the nation's programs. The new Division will perform research and development in electrical and other advanced propulsion systems. Y. C. Lee has been appointed Manager . . . . Liquid Rocket Plant, Sacramento, has appointed Capt. Robert C. Truax, USN (Ret.), as Director of Advanced Development. Cecil W. Wawra of Paris has been named Director of European Operations.

• **Aeroquip Corp.** has appointed John M. Van Dam as General Manager of its General Logistics Division, Burbank, Calif.

• **American Bosch Arma Corp.** has announced acquisition of Ensign Carburetor Co., Fullerton, Calif., as a wholly-owned subsidiary. Norton C. Sather has been named Manager of the new division. Paul W. Ensign and Roy F. Ensign, who took over the management of the company in 1935, will remain on a consulting basis. W. W. (Win) Harris has been appointed Manager of American Bosch Arma's West Coast office.

• **Bendix Aviation Corp.** has appointed Eldred E. Evans as General Manager and Robert J. Quirk as Assistant General Manager of the Kansas City Division . . . . Pacific Division has named Richard B. Laver as Comptroller.

• **Chicago Aerial Industries, Inc.,** has announced the appointments of Jerome S. Goldhammer as Manager, Reconnaissaance Systems and Planning, and Charles Hybarger as Marketing Manager.

• **Douglas Aircraft Co., Inc.,** has changed the name of the Human Factors Group to the Life Sciences Group. Dr. E. B. Konecci continues to head the group. The Life Sciences Group is responsible for all human factors and bio-astronautical activity in the Missiles and Space Systems Engineering Department.

• **General Dynamics Corp.** has taken a step to guarantee continued reliability of its military and commercial products by formation of a Reliability Panel. Membership consists of key scientists, quality control engineers and reliability experts from all its Divisions. J. Y. McClure, Manager of Quality Control at Convair-Fort Worth, is Chairman of the group . . . . Convair has named Elwood D. Bryant as Assistant to the Manager of Operations, and Ross C. Wills as Manager of its Omaha office . . . . Stromberg-Carlson has announced the following appointments: Franklyn E. Dailey, Jr., as Manager of Planning—San Diego and Walter E. Sargent as Supervisor of Production Engineering—San Diego.

• **General Electric Co** . . . . Defense Electronics Division has announced formation of an Advanced Systems Engineering Operation in the Missile and Space Vehicle Department, and appointment of Howard M. Wittner as Manager, plus naming of Sub-Operation Managers, as follows: Robert L. Francisco, Advanced Test, Search, and Recovery; C. Frank Hix, Jr., Advanced Missile Engineering; Richard A. Passman, Advanced Re-Entry Vehicle Engineering; Robert R. Reid, Advanced Satellite and Probe Engineering; Stanley C. Tracz, Global Surveillance Study Operation; L. W. Warzecha, Advanced Space Vehicle Engineering.

Attention Members!

All Members of the Institute are invited to submit material concerning their activities for publication in the news columns of Aero/Space Engineering.

• **General Precision Equipment Corp** . . . . Kearfott Co., Inc., has announced a recent expansion of its plant facilities in Asheville, N.C. Totalling 82,500 sq. ft. and employing 700 skilled craftsmen, this new addition increases the company's capacity to meet current and future demands for high precision electromechanical rotary components.

• **Janitrol Aircraft Division,** Surface Combustion Corp., has appointed James W. Ashby as General Manager. Joseph F. Hill has been named Manager of Engineering.

• **Lockheed Aircraft Corp** . . . . Georgia Division has named Lt. Col. Donald Williamson, USAF (Ret.), as Small Business Coordinator.

• **The Martin Co.** has appointed Adolph Vlcek, Jr., to the position of Director of Manufacturing at the Baltimore Division.

• **Meletron Corp.** has announced two additions to its staff: Gerald E. Schmitt has joined as Customer Relations Manager and Frank Cockings as Field Engineer in the Sales Division.

• **Radio Corporation of America,** Defense Electronic Products, has announced that Dr. Raymond M. Wilmotte has joined the staff of Advanced Military Systems.

• **Solar Aircraft Co.** has named William C. Benson as Project Engineer, Ground Support Equipment.

• **Thompson Ramo Wooldridge Inc.** has purchased a controlling interest in Magna Products, Inc., of Santa Fe Springs, Calif., producers of specialty chemicals and electronic instruments for the chemical and petroleum industries. Plans for expansion of the West Coast Division of TRW's Tapco Group with construction of a $2 million aircraft and missile components plant in Orange County have been announced . . . . Thompson-Ramo-Wooldridge Products Co. has named Wayne J. King as Field Engineering Manager and Emil Borgers as Associate Manager of the Programming Department. Additions to the staff are Kieran D. Brennan as a Manufacturing Liaison Engineer and Mrs. Margaret E. Brooks as a Computer Programmer. A Systems Engineering Office has been established in Atlantic City, N.J., and Harold A. Keit has been named to head the new office.

• **Vertol Aircraft Corp.** has appointed Thomas P. Peppler Project Manager and Harvey H. Klein Project Engineer for their YHC-1B helicopter program. Other promotions are: Kenneth Gillmore to Chief of Preliminary Design; John Diamond to Preliminary Design Project Engineer; Joseph Reich to Project Engineer on the H-21 and Vertol 44 programs; and William B. Peck to Chief Stress Engineer.

(IAS News, continued on page 68)

Another Operating PLUS for United Air Lines DC-8 Jet Mainliners

The B&H JETCAL® ANALYZER

ASSURES... *maximum range, lower operating costs, greater dependability of schedule operation, better assurance of on-time arrivals at planned destinations!*

TESTS EGT SYSTEM ACCURACY to ±4°C (functionally, without running the engines).
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Pesco electronic cooling packages . . .

integral, miniaturized design saves space and weight

Pesco pioneers a new concept in cooling packages for electronic equipment. Miniaturization produces remarkable savings in weight and envelope size. Integral design eliminates external tubing and fittings, avoids leakage problems, simplifies maintenance and assures quiet operation.

There are performance advantages, too. The Package shown above provides 250 watt heat absorption in a 10″x 5½″x 5½″ unit weighing 6 pounds! Built-in protective features guard against overheating of the Package, overheating of electronic equipment and loss of coolant. This Pesco custom-design concept can be applied to any cooling problem.

You can move from problem to prototype faster because Pesco alone produces all necessary components—axial flow fans, electric motors, coolant pumps, temperature sensing and relief valves and reservoirs. Single responsibility, true systems engineering and close design coordination assure matched component performance and maximum reliability.

For your Electronic Cooling Package needs, utilize Pesco's unique background and advanced designs. Contact your nearest Pesco sales office or:

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PESCO . . . engineering Pesco production BW PESCO BORG-WARNER TRADEMARK *means progress in aircraft/missile systems and accessories*

LETTERS to the Editor

In Acknowledgment

■ As coauthor with the late Louis N. Ridenour of "Electronic and Communications Aspects of Space Flight," which appeared in the April issue of AERO/SPACE ENGINEERING, I would like to make the following comments on, and additions to, the article:

(1) In Table 1, page 55, it should have been indicated that the trajectory calculations involved launching from Florida with 3 dimensional transfer paths using actual planetary ephemerides.

(2) In line 9 of the right-hand column of page 57, replace "$3^1/_2$ bits per sec." by "4 bits per sec."

(3) Acknowledgment should be given to the many members of the Research and Project Technical Staffs of the Lockheed Missile Systems Division who furnished for the paper technical information and commentary drawn from broad acquaintance with the relevant literature in the field; of special aid and direct usefulness in this latter connection should be mentioned material originally compiled in the spring of 1958 by members of the Engineering Division of The RAND Corporation, Santa Monica, Calif. (some of which has since been briefly summarized in the Staff Report of the Select Committee on Astronautics and Space Exploration).

B. W. Augenstein
Chief Scientist's Staff
Scientific Advisor to XA Project
Lockheed Aircraft Corp.
Missile Systems Div.
Sunnyvale, Calif.

✦ ✦ ✦

More on Reliability

■ In further comment regarding Reliability Engineering, I would like to expand some of the areas which were aptly identified by Lewis A. Rodert in the May Letters Section of AERO/SPACE ENGINEERING.

The steps which he has proposed as fostering continued development in the field of Reliability Engineering are certainly sound and invite further definitive treatment by other readers. However, I would like to emphasize that, in my opinion, the area requiring our greatest concentration of effort at this point is the implementation of the knowledge which we have fully developed.

Reliability philosophy and its resulting arithmetic reflected in Mr. Rodert's letter and developed by such pioneers as Chuck Ryerson of RCA is well established. However, its true implementation in the mechanical field, at least, is woefully weak and sporadic. Implementation of a Reliability Program which follows the stringent rules of our arithmetic is a gigantic task for any given design/fabrication cycle and is a rare occurrence indeed. Such a program not only is demanding of the highest degree of technical integrity but also cuts across the fabulously complex lines of inter/intra contractor politics, prejudices, concepts of design, production procedures, and the economic squeeze play of competitive bidding. Thus, even at this late date, most "reliability" is still a sales function, and it is the unusual contract indeed which can truly state that it has a well-established program in effect.

For my part, then, I am emphasizing the urgent need to concentrate on a forthright and energetic implementation of its current "state of the art," as well as an "advancement of the science."

The comments in this letter are personal expressions.

John R. Burnett, MIAS
Senior Research Engineer
San Diego, Calif.

✦ ✦ ✦

For Aviation Hall of Fame

■ I wish to submit the following recommendation via Letters to the Editor for comments from IAS members.

I believe it would be desirable to consider the possibilities of an "Aviation Hall of Fame" dedicated to those who have sacrificed their lives in the experiments and development of all types of aircraft. Perhaps a fitting spot would be in the Aviation Building of the Smithsonian Institution, with a picture of the individual, outlining the test flight or equipment under test, and contributing factors resulting in the risk of life in these developmental areas.

I am sure that the aviation industry would be willing to set up the necessary funds for this purpose to support a designated committee to accomplish this noteworthy recognition of pilots and others who have given their lives to advancement of the aeronautical sciences and to industrial progress.

An Associate Fellow

The Editors welcome letters from readers, although none can be acknowledged. All must be signed, but identities will be withheld on request.

Weightlessness Premise Wrong?

■ In response to Mr. Charavay's letter, which appeared in AERO/SPACE ENGINEERING for July, I would like to make the following comments about his remarks concerning weightlessness. His one short paragraph on the subject can be formed into the following logical syllogism:

MAJOR PREMISE: "All forms of inertia, acceleration, or centrifugal force depend on weight and motion."
MINOR PREMISE: In a nearly perfect vacuum, which we find in outer space, there is weightlessness.
CONCLUSION: "Therefore, without weight you have nothing."

Upon examining this syllogism, immediate exception can be taken with the major premise. All forms of inertia, acceleration, or centrifugal force do not depend upon weight but mass. The professors of the engineering, mathematics, and physics departments of the University of Wichita have impressed upon the students attending their classes that there is a difference between mass and weight, although under some conditions they are synonymous.

I suggest Mr. Charavay try inserting into the Newtonian equation, $F = ma$, pound (weight) units in place of slug (mass) units and obtaining a correct answer. He must remember that weight is commonly defined as the force of gravitational attraction exerted on a body, whereas mass is a measure of a body's inertia, two different concepts.

As for his question of why particles leave a strong gravitational field and travel to a weaker one, I might answer by saying for the same reason a particle or body which has been accelerated to "escape velocity" will leave a strong gravitational field—i.e., space rockets.

Frank L. Wright
IAS Student Chapter
University of Wichita
Wichita, Kan.

✦ ✦ ✦

Finds Letter "Nonsense"

■ I would like to ask whether the Editor's Note at the end of Associate Fellow Frederick Charavay's letter in the July issue of AERO/SPACE ENGINEERING really invites unnecessary comments to such nonsense, or is it just a joke to disguise the embarrassment for publishing such nonsense.

L. S. Dzung, MIAS
Baden, Switzerland

XUM

Systems
Electronic / *Engineers*
Mechanical

NEWS OF ENGINEERING OPPORTUNITIES

OPEN ON MOST "TALKED ABOUT"

MISSILE OF THEM ALL

POLARIS

...and other diverse and complex weapons projects at General Electric's Ordnance Department in the Berkshires*

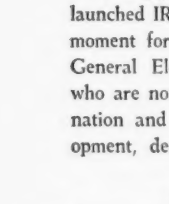
When the first operational Polaris missiles are installed in the "George Washington" —first atomic submarine specifically designed as floating platform for the Navy's undersea-launched IRBM s — it will be a day of great moment for the engineers and scientists at General Electric's Ordnance Department, who are now pouring their energies, imagination and technical skills into the development, design and production of Polaris Fire Control and Inertial Guidance Systems.

A day of celebration — but also one that ushers in new and other challenging problems — for the push to develop the next generation of long-range underwater ballistic missiles and kindred advanced weapons and weapon systems will be on.

There are openings now for engineers (*EEs or MEs*) with two to seven years' experience in these areas:

SYSTEMS DEVELOPMENT / SYSTEMS DESIGN OR EVALUATION
FIRE CONTROL ENGINEERING / INERTIAL COMPONENT DESIGN / COMPUTER DEVELOPMENT
ELECTRONIC CIRCUIT DEVELOPMENT / STRUCTURAL DESIGN AND VIBRATIONS
FIELD SERVICE & EVALUATION / QUALITY ASSURANCE & RELIABILITY ENGINEERING
ELECTRO-MECHANICAL DESIGN / ADVANCED PRODUCTION ENGINEERING
ELECTRICAL DISTRIBUTION SYSTEMS ENGINEERING / PLANT FACILITIES ENGINEERING
PRODUCT SERVICE INSTRUCTION / PRODUCT PLANNING / SALES ENGINEERING
CONTRACT ADMINISTRATION / TECHNICAL WRITING

Field Test Engineering (Florida, California and several naval stations in continental U.S.)
Also technician openings for graduates with missile experience



Write in strict confidence to: Mr. R. O'Brien, Dept. 2-MI
Ordnance Department of the Defense Electronics Division
GENERAL ELECTRIC
100 Plastics Avenue, Pittsfield, Mass.

Additional Projects Under Investigation at the Ordnance Department. Urgent, vital and engrossing as the Department's share in the Fleet Ballistic Missile Program is, it is just one of the diverse activities here that today offer engineers a progression of challenging assignments on: **Atlas Guidance Equipment • Talos Handling and Launching Equipment • Advanced Torpedo Development • Tartar Fire Control**

DATELINE world

PROFESSIONAL NOTES AND REPORTS

Engineering and Scientific Briefs from Correspondents Around the Globe

British Convertiplane Hailed as Design Success

◆ Export orders for the British Fairey Rotodyne indicate that this rotary wing convertiplane has been accepted as a successful design.

The twin-engine prototype aircraft made its first flight in November, 1957, some 8 years after the design was originated to satisfy a British European Airways requirement for a short-haul rotary wing airliner to carry at least 30–35 passengers. After a showing at the Farnborough Show in September, 1958, Okanagan Helicopters, Ltd. (of British Columbia, Canada), ordered a Rotodyne. (Okanagan is the world's largest commercial operator of helicopters, having a fleet of more than 50 helicopters.) Early in 1959, New York Airways announced an order for five Rotodynes with an option for 15 more. However, the NYA order was for a larger version, designed but not yet built when the order was placed.

Tyne engines replace the Eland engines in the larger version. Various size and performance figures for the Eland-powered and Tyne-powered versions are given for comparison in Table 1.

The Fairey Rotodyne has a single four-bladed rotor mounted over the center of a conventional fuselage. A high wing of 47-ft. span has underslung engine nacelles located halfway in from the wing tips. The turboprop engines drive auxiliary compressors that provide air to jets at the tips of the rotor blades. Fuel piped through the blades is burned at the tips to furnish rotor power for vertical take-off. In order to provide sufficient air for continued burning in case of single-engine failure, dual-ducting channels the air from each engine to separate pairs of opposite blades.

Transition to forward flight is accomplished first by differential pitch of the rotor in a normal helicopter manner, then power is gradually phased by a hydraulic clutch from the auxiliary compressors to the propellers, until the rotor is autorotating without power. In forward flight, the wing loading equals about 60 per cent of the total weight of the aircraft. The rotor cannot be unloaded any more than that without sacrificing some of the lateral and pitch control, both of which are maintained in the rotor. During forward flight at the higher speeds, directional control is accomplished by aerodynamic rudders on the twin vertical tails, but is phased into differential propeller thrust for lower speeds. As a result, the propeller power is never phased to zero for vertical take-offs and landings, although the compressor/rotor power is phased to zero for forward flight speeds.

Table 1.

	Eland	Tyne
Total take-off power (e.s.hp.)	7,000	10,000
Take-off weight (lb.)	39,000	50,000
Passengers, normal (no.)	40	57
Freight (lb.)	10,000	15,000
Fuselage length (ft.)	58.7	64.5
Rotor diameter (ft.)	90	104
Maximum speed (knots)	165	175
Cruise speed (knots)	160	160
Stage length (n.m.)	225	250

Auto Bodies, Dies, Made From Plastics by Soviets

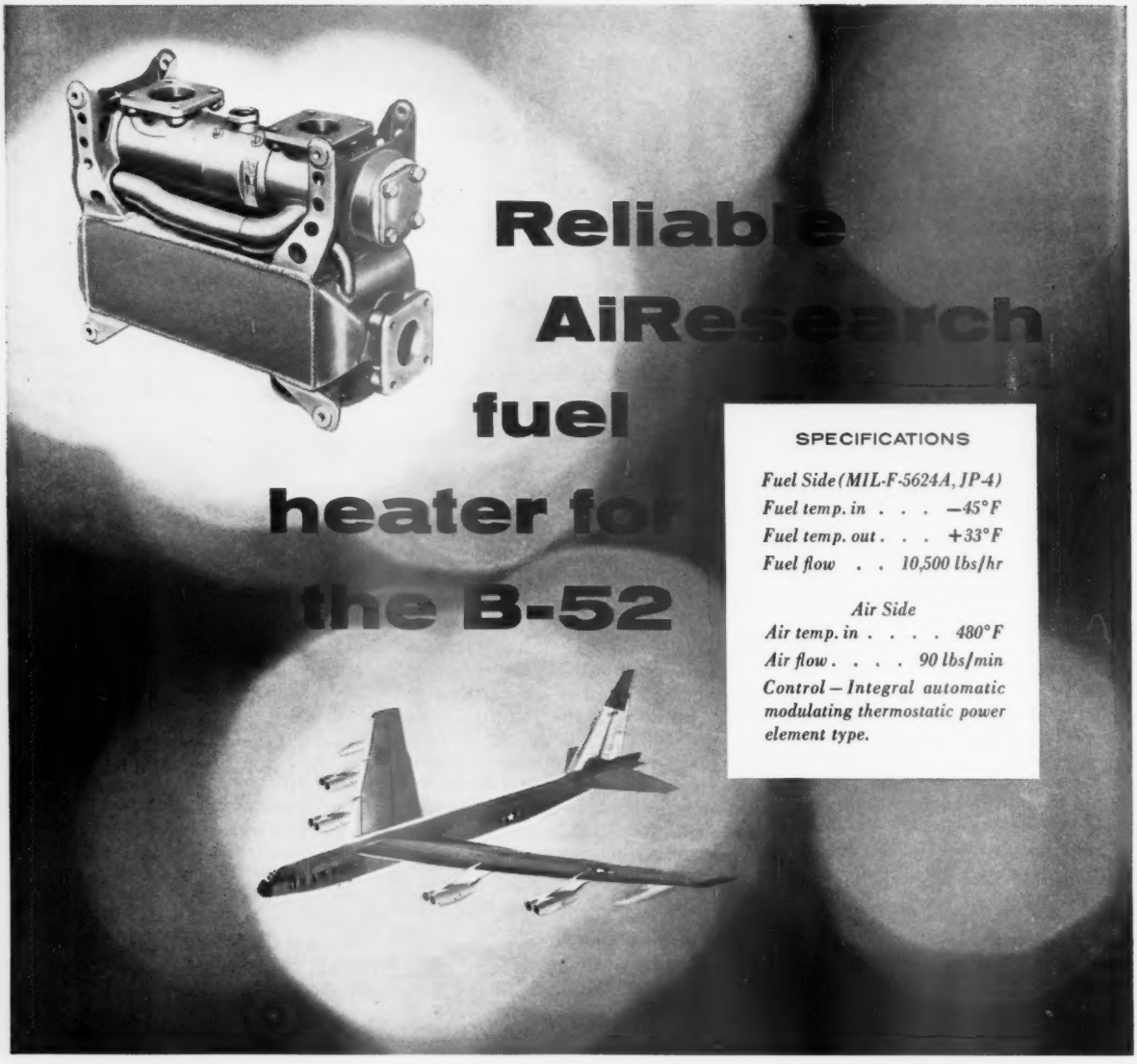
◆ Summing up U.S.S.R. interest in synthetic materials, which is considered by some Western experts the most revolutionary area in industrial development in the Soviet Union today, Dr. G. Kolesnikov, laboratory chief of the Academy of Sciences' Institute of Elemental Compounds, points to some of the diverse uses Soviet industry has found for plastics. In the auto industry, Dr. Kolesnikov said, automobile bodies are now made of plastic. Also, plastic dies, some of which are simply cast into gypsum molds, have been introduced. These dies are made in one tenth of the time required for the construction of identical steel dies, according to the Soviet spokesman, and are four times lighter in weight. He points also to the great weight advantage found in using vinyl plastics, instead of lead, in making pickling and electrolytic baths. Further uses mentioned by Dr. Kolesnikov include synthetic resins for rubber and for asbestos brake shoes of excellent durability, such new plastics as ion-exchange resins (ionites) for boiling water purification, glass fiber pipes which will withstand pressures up to 300 atmospheres, and polyethylene water pipes which do not crack even though the water freezes and should serve for 50 years without deterioration.

Av-CIR Report Discusses Man's Survival of 162g Fall

◆ A review of a scaffold worker's free fall of 145–150 ft., involving an impact in loose rubble of about 162*g* for 0.014 sec. and an onset rate in excess of 22,000*g* per sec.—which he survived—has been issued by Aviation Crash Injury Research of Cornell University (now of the Flight Safety Foundation) under Office of Naval Research Contract No. Nonr 401(21). "Human Impact Survival at 162*g*" is the condensed version of a paper originally written by Hugh De Haven and Ruth M. Petry, of the Av-CIR staff, and is presented for engineering consideration because of increased interest in human tolerance to impact loads, particularly in relation to crash landings of manned space vehicles.

The author, A. Howard Hasbrook, Director of Av-CIR, asserts in his discussion: "The fact that a number of people have survived free falls involving decelerations in the 100–200g range and rates of onset as high as 22,000*g* per second, while others have been killed in aircraft accidents involving less than 15*g*, indicates that the strength of the human body has not been given due consideration in relation to crash safety design of aircraft. Too, such free fall data may be useful to engineers designing future space vehicles."

Copies of the report may be obtained in limited quantity from Aviation Crash Injury Research of the Flight Safety Foundation, 2713 E. Airline Way, Sky Harbor Airport, Phoenix, Ariz.


Reliable
AiResearch
fuel
heater for
the B-52
SPECIFICATIONS
Fuel Side (MIL-F-5624A, JP-4)
Fuel temp. in . . . −45°F
Fuel temp. out . . . +33°F
Fuel flow . . 10,500 lbs/hr
Air Side
Air temp. in . . . . 480°F
Air flow . . . . 90 lbs/min
Control – Integral automatic modulating thermostatic power element type.

• AiResearch is now in quantity production of an extremely reliable engine bleed air fuel heater which prevents icing in the B-52 engine fuel system during flight. This unit utilizes a minimum of hot compressor bleed air automatically modulated to keep fuel temperature above 32°F. Heating the fuel in flight overcomes the icing problems resulting from the presence of a limited quantity of water in the airplane fuel system regardless of the source of such water contamination.

Efficient design and development capability made it possible for AiResearch to build an efficient lightweight bleed air fuel heater system on an expedited schedule of seven month's time from initial order to production delivery. AiResearch has been the world's largest and most experienced manufacturer of aircraft heat transfer systems for 20 years. Outstanding design and production facilities, supported by extensive laboratory and test equipment, enable AiResearch to quantity-produce fuel heaters of any configuration in minimum time while maintaining rigid quality controls.

In addition to the B-52 fuel heater, AiResearch is also producing several other types of plate and fin air-to-fuel as well as shell and tube oil-to-fuel heaters for both military and commercial aircraft applications. Your inquiries are invited.

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GUEST EDITORIAL

Engineering and Science in Space

H. Guyford Stever, FIAS

Massachusetts Institute of Technology

A great rocket mounted ready to fire into space is a thrilling sight, and a successful launching gives everyone even remotely connected with its creation and existence a deep sense of satisfaction and pride. Such a rocket is a useful machine brought into being by a pressing need of society and, being a useful machine, represents a typical end product of engineering activity. It is a new kind of machine; its many elements are on the forefront of component developments, and the synthesis of those components into a rocket system is one of the most challenging engineering design problems.

How much activity by scientists is involved in the conception, design, building, and firing of such a rocket? In one sense a great deal, for among definitions of a scientist is "one learned in the natural sciences." Surely the difficult problems of development in propulsion, guidance, structures, and systems design require knowledge of physics, thermodynamics, mechanics, chemistry, electromagnetics, and a host of other sciences. But in this sense the scientific knowledge is just one of the component bodies of knowledge and skill called upon by engineers; it is combined with art and purposefulness, in an economic manner, to create a useful machine in the time-honored way of engineers.

Scientists of the purer variety have a somewhat narrower definition of their profession. They include in their ranks only those working to discover new laws or facts, to add to or clarify the already overwhelming body of knowledge in the physical sciences. In this narrower sense, the achievement of space flight in itself is not a scientific achievement. Still, much of our space activity has to do with science in this narrower sense, not in the accomplishment of space flight (for this success belongs to the engineers), but rather in the employment of our space flight capability in the conduct of scientific experiments. The scientific research in astronomy, astrophysics, biology, and chemistry, among other sciences, which can be accomplished using our newly developed rockets to carry instruments into the previously unreached regions of the solar system, has been listed often and need not be gone into here. Suffice it to say, now that the total reaction to engineering progress in space flight (partly a reaction of fear of military weakness and loss of scientific leadership and partly recognition of the eventual great importance of space flight) has convinced the leaders and people of this country to support a major space effort, many research scientists are developing a great interest.

Dr. H. Guyford Stever, Professor of Aeronautics and Astronautics at the Massachusetts Institute of Technology, has made numerous contributions to the field of aeronautics. In addition to his active role in teaching and administration at M.I.T., he has rendered service to the USAF on several advisory groups culminating in his service from 1955 to 1956 as Chief Scientist of the Air Force. He has been a member of the USAF Scientific Advisory Board since 1956 and is now Vice-Chairman. He has recently been appointed Chairman of the NASA Research Advisory Committee on Missile and Spacecraft Aerodynamics. Dr. Stever was graduated from Colgate University in 1938, and in 1941 he received his doctorate in physics at the California Institute of Technology, where he did research on cosmic rays and electronics for Geiger counter experiments. In 1958 he was awarded an Honorary Doctor of Science degree by Colgate University.

The space engineers themselves are quite interested in some of the scientific experiments, for their developments are fast on the heels of the progress made in science—e.g., the measurements made in space of radiation from the sun are wanted by the astrophysicists to find out what physical processes are taking place. These same measurements are of equal interest to the space flight engineers to enable them to protect instrumentation and humans aboard spacecraft from harmful effects of the radiation, or to permit them to design devices to use the radiation as a source of local energy on the spaceship.

Often in modern life, with the ascendancy of science, one gains the impression that engineering is the complete debtor of science, that there is a one-way flow of information and capability, that the engineer can only wait for the scientist to discover new laws and facts so that he, the engineer, eventually can apply them. In some cases of modern technologies (space flight and ballistic missiles), where scientific research and engineering design are so closely mingled, the impression is given that to the scientist belongs the full credit for all achievements. Nothing could be farther from the truth. Of course there is a debt owed by engineers;

(*Continued on page 42*)

Centuries of groping toward the conquest of space have resulted in breaking the barrier of orbital flight. Maneuverability in space at the will of a crew is the next challenge. The nature of the vehicle proposed is a glider with a large rocket engine.

Space Applications for Rocket Vehicles

Everett T. Welmers, AFIAS

Bell Aircraft Corporation

As THE second year of the Space Age draws to a close, the imaginations of mankind, as well as the vehicles men have produced, are firmly planted in the heavens. Eleven moons have successfully been launched; four of these satellites are still tracing out their elliptical orbits every two hours. Two vehicles have escaped the gravitational field of the Earth and assumed paths about the sun—the first man-made planets. The unprecedented power of rocket boosters, coupled with a precision of control rarely required under laboratory conditions, has enabled the Soviet Union and the United States to reach out into space with vehicles of different configurations for various purposes.

The successes so far attained have answered many questions and satisfied many ambitions. But they also have raised many more problems and encouraged magnificently imaginative plans, previously considered only impossible dreams. Vehicles have been given specific assignments to report on conditions in whatever orbit they were placed. The data returned have been significant, though very limited. The space paths swept out were usually sufficiently close to those intended—at least when orbit was attained—so that instrumentation was appropriate. But all have been characterized by a very brief period of active flight path control compared to the total duration of significant flight time. Space vehicles to date have been more like artillery shells, subjected to guidance only when inside the gun, rather than like aircraft or active target-seeking missiles, controlled for their entire life. Although rockets are uniquely independent of atmospheric oxidizers, rapid release of enormous energy and light weight have been equally useful properties. The ability to maneuver in space and to rendezvous with another space object is essential to the conquest of space. Modification of the radius and plane of the orbit, as well as attitude changes of the vehicle itself, are required. The critical interceptions between the vehicle and the Earth, as well as possible landings on Mars and Venus, suggest exploitation of the atmosphere where available. A rocket vehicle possessing both space and aerodynamic maneuverability becomes a practical device for repetitive and purposeful missions. This seems an appropriate and rapidly attainable goal—man in space, under man's control, doing what man desires.

Historical Background

Ancient

As might have been expected, the earliest conceptions of space vehicles involved attempts to apply physical principles appropriate only to the Earth and its atmosphere. Icarus reportedly flew so close to the sun that his wing structure melted—but the ineffectiveness of such propulsive surfaces at high altitudes was not suspected. Balloons which could rise to reach the moon were proposed, without anticipating the rapid reduction of atmospheric density. Lukian, about 160 A.D., described trips to the moon, in one case propelled by a whirlwind and, in another, flying with bird's wings. Eagles tied to a platform formed the space vehicle of Regiomontanus—an ineffective attempt to harness masters of the sky to a simple airframe. Cyrano de Bergerac, in 1649, published *A Trip to the Moon*, in which a variety of vehicles and methods of propulsion are described, only one of which has any physical soundness. In the play by Rostand, Cyrano describes six unique ways of "violating the virgin skies" (then claims he used a seventh). The most "scientific" is the third:

"After jumping off like a grasshopper on steel springs, I could, by successive explosions of gunpowder, hurl myself into the blue meadows where the stars are feeding."

Jules Verne, in *From the Earth to the Moon*,[1] described not only a vehicle, propulsion system, and passenger compartments, but also the velocity required and the orbit which must be attained.

Modern

Even though such imaginative exercises did not contribute directly to scientific progress, they have been continually significant as sources of ideas and challenges to action. Concepts based on firm physical princi-

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ples, coupled with an appreciation of the problems of realization, became significant at the beginning of the 20th Century. As early as 1895, Konstantin E. Tsiolkovskii (1857–1935) discussed artificial satellites, and in 1903 published *Investigation of World Spaces by Reactive Instruments*.[2, 3] Although the work of Goddard[4] and that of German rocket enthusiasts two decades later was primarily oriented toward solving engineering problems, proving that rocket engines would actually operate, the unique application to space propulsion was always a goal.

Attempts to find a "breakthrough" for the problem of long-range bombing led Saenger and Bredt to studies of rocket-boosted gliders.[5, 6] Much of the interest in their work is due to the re-entry problem; a skip-glide path was suggested for the reduction of kinetic energy without continuous aerodynamic heating. As an extension of the V-2 developments, a group at Peenemünde designed and tested a rocket-glider, the A-9, again for the purpose of extending bombing ranges.[7]

Russian interest in vehicles of this type is based partially on the same long-range bomber concern. However, a paper by Shternfeld in 1954 on *Problems of Cosmic Flight*[8] discussed rocket-propelled space vehicles and proposed that gliding flight be used for landing on the Earth, Mars, or Venus.

In the United States, a continuation of the Peenemünde work has led to proposals for commercial and military applications of rocket-boosted gliders by Dr. Walter Dornberger. A careful analysis of the efficiency of such vehicles for very long-range terrestrial applications has been made by R. Cornog,[8] with the conclusion that the rocket-propelled airplane can be an economical form of transportation.

Vehicle Requirements

Many applications of satellites and space probes do not require a human crew. However, although man could throw a stone, shoot an arrow, or fire a shell, he was not satisfied until he had a device in which he, himself, could move through the atmosphere. This situation will or even now does exist regarding space. Whether spacecraft are used in scientific or military roles, a manned vehicle is essential for servicing or inspecting unmanned space stations, for a space station itself, as a shuttle between Earth and manned satellites, or for exploring far regions of space.

Repetitive Landing and Take-Off

Such an operational concept of a rocket vehicle in space implies repetitive usage. The inaccessibility or unfriendly environment of much of the Earth's surface emphasizes the desirability of landing at a predesignated base. If appropriate techniques for ejection from orbit are available, purely ballistic flight can give general area accuracy.[9] Precise touchdown can be most easily accomplished by utilizing aerodynamic control under dictates of an automatic landing system. Aerodynamic maneuvering forces would be trivial (0.01g) at 300,000 ft.; effectivity at 80,000 ft. would be significant, 1/3g; below 65,000 ft. more than 2.5g would be available, leading to structural and other limitations on control, rather than aerodynamic.

A glider-type vehicle is also desirable in making contact with other planets possessing atmosphere. Re-entry into the atmosphere of Venus where surface density is approximately 13 times that of the Earth would be similar to that of the Earth. Mars, with 1/13th the atmospheric density at the surface, will present lower decelerations and lower heating rates. Gazley[10] has discussed the general problem of planetary atmospheric re-entry.

An "escape" rocket, powerful enough to eject the vehicle from a malfunctioning booster system at or near take-off, is desirable, both for pilot safety and for repetitive use of the airframe. The same rocket could be used for the major maneuvering requirements in space.

Variation of Orbital Plane

Assuming that a vehicle has been placed into orbit, aspects of maneuverability can be considered sepa-

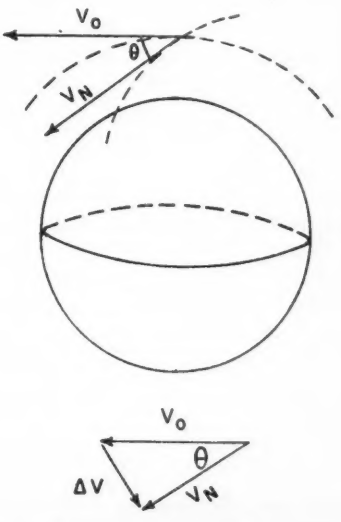

Fig. 1. Change of orbit plane.

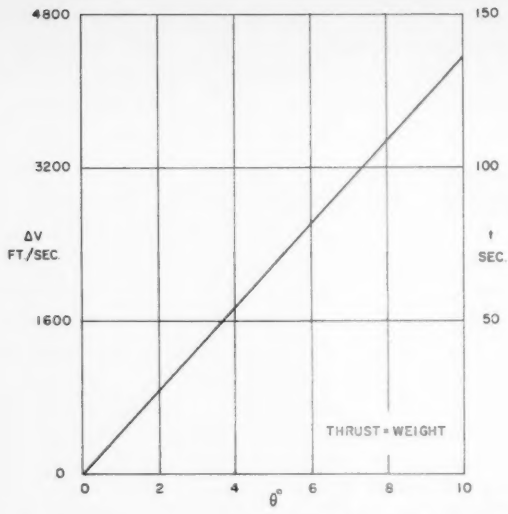

Fig. 2. Velocity increment and time required for change in orbital plane.

rately, even though combinations of these will usually be applied simultaneously. For variations of the orbital plane, the velocity vector must alter direction without change of length. Then, as in Fig. 1,

$$\Delta V = V_N - V_0$$

$$|\Delta V| = 2\,|V_0| \sin \theta/2,\ |V_N| = |V_0|$$

Obviously, a 60° shift requires a velocity increment equal to the original velocity, and a 180° change requires double. If orbital velocity is 25,000 ft./sec., the $|\Delta V|$ required for orbital plane change of θ is shown in Fig. 2. If thrust along ΔV is equal to vehicle weight, the time required to attain the new velocity is shown as the right ordinate. Precision launching is clearly necessary since variations of more than 5° will require placing very large propellant loads into orbit.

Variation of Orbital Radii

Variation in the size or shape of the orbit involves changes in total energy, kinetic plus potential, and in the period of revolution. If E is the total energy per unit mass with respect to a state of rest on the Earth's surface, this dependence on orbit geometry can be expressed as:

$$E = (\lambda/r_0) - [\lambda/(r_a + r_p)]$$

here r_a and r_p are lengths of the radius vectors at apogee and perigee, r_o is the radius of the Earth, and

$$\lambda = g_0 r_0^2 = 14.059 \times 10^{15}\ \text{ft.}^3/\text{sec.}^2$$

A circular orbit at the Earth's surface results in

$$E = (\lambda/r_0) - (\lambda/2r_0) = \lambda/2r_0 = 336 \times 10^6\ \text{ft.}^2/\text{sec.}^2$$

The energy required for escape from the gravitational field of the Earth is

$$E = \lambda/r_0 = 672 \times 10^6\ \text{ft.}^2/\text{sec.}^2$$

since $r_a + r_p$ is then infinite.

For convenience, the altitudes, h_a and h_p, above the Earth's surface may be used:

$$r_a + r_p = h_a + h_p + 2r_0$$

Fig. 3 shows total energy E and period P plotted relative to the sum of these altitudes, $h_a + h_p$. (Note that E scale increases downwards.)

Differentiating E with respect to an orbital radius,

$$dE/dr = \lambda/(r_a + r_p)^2$$

Evaluating at the Earth's surface (where $E = 336$), eight energy units per unit of mass are required for each foot change in orbital radius, increasing as radii increase. At the required altitude for a 24 hour satellite, 22,400 miles, $E = 621 \times 10^6$, 85 per cent more than for a surface orbit, but $dE/dr = 0.18$. So small an energy change per ft. change in orbit radius is likely to be balanced by much larger errors in orbit dimensions at such great distances.

Variation of Attitude

Attitude control is intended to accomplish two tasks. The first defines the application of other forces by rotating the vehicle in the appropriate direction. A fixed rocket thrust can then be used for changing orbit plane and adding or subtracting energy to modify orbit geometry. Also, the aerodynamic forces involved in re-entry can be properly applied before aerodynamic surfaces can be used. The second task is orientation of the vehicle in order to accomplish specific missions, such as presenting the proper surface to a satellite being overtaken, directing instruments toward desired phenomena, or accepting interchange of men and material in space.

Considerable experience with such systems exists, including the X 1-B research airplane and VTOL craft. A typical system could consist of small rockets using hydrogen peroxide as a mono-propellant, decomposed upon contact with a silver catalyst bed. For 90 per cent, H_2O_2, a specific impulse of 160 sec. at in-

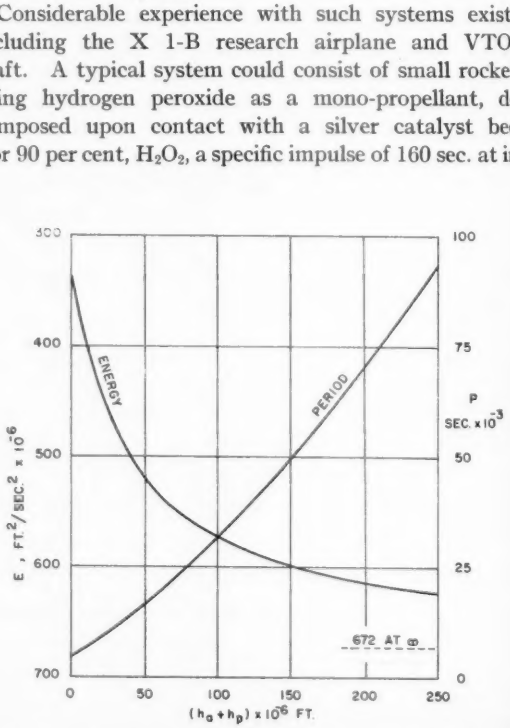

Fig. 3. Relation of orbit size to period and energy per unit mass.

finite altitude is attainable with 200 psia chamber pressure; this rises to 180 sec. with 99 per cent concentration. Fig. 4 indicates the relation between total impulse and system weight, including the H_2O_2 tank, a helium pressurization tank, and nozzles with an area ratio of 12. Higher thrust levels or more nozzles add about 3 lbs. per 100 lbs. of thrust. On-off, proportional, or more sophisticated variants of control have been designed. Total impulse requirements for a space vehicle depend on maneuvering requirements and duration aloft, but values in the upper-right quadrant of Fig. 4 will likely be applicable.

Problems of Significance

A vehicle satisfying the requirements described can be designed to give a configuration as depicted by the front cover of this issue of AERO/SPACE ENGINEERING. However, the road to realization of such a concept is obstructed by numerous problems of particular significance. A few will be described briefly.

Launching

Programs for large boosters are already in progress, giving hardware appropriate to the vehicle under discussion. If the space vehicle is originally designed with large tanks for extensive maneuvering, first flights can be made with small amounts of propellants, increasing as booster thrusts rise. Thus, missions can expand without change of the basic spacecraft. Reliability of boosters when men are in upper stages will continue to be a most critical problem. If repetitive flights are to be made, costs become serious; for first stages, more emphasis must be placed on low cost propellants, and perhaps recoverable cases, than on high specific impulses.

Environment

Most environmental problems for both crew and equipment will already have been studied by satellites, probes, and projects such as Mercury. Complete flexibility regarding the radiation bands is not as yet possible; shielding may be required or techniques may be found to avoid the most critical regions through choice of launch point and orbit. Problems of food and oxygen for the crew are not as serious as in a permanent manned station, but these may form significant cargoes on supply missions. The crew must be able to carry out a mission in comfort, or the advantage of the human element will vanish.

Propulsion

A rocket engine for maneuvering in space poses a challenge. It must be restartable, have a very high specific impulse and low weight, must be accurately controlled, and variable thrust would be desirable—in fact, it should be the ideal rocket engine. Exotic propellants, such as fluorine or new chemicals created for this specific purpose, are desirable. Refinements here justify high costs.

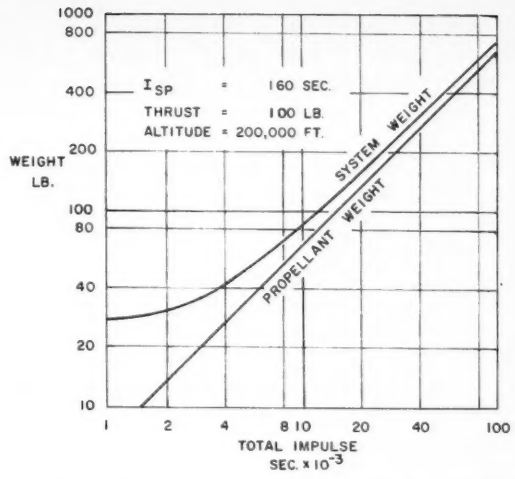

Fig. 4. Reaction controls—weights of H_2O_2 system for total impulse requirements.

Navigation

Experience with the construction and launching of unmanned satellites can be expected to improve the accuracy of injection into orbit. Maneuverability in space can, of course, simplify the problem of precisely attaining an original orbit, but only at the expense of energy available for other maneuvers. Attainment of precision paths will likely be an early application of maneuverable space vehicles.

Determination of satellite orbits from the Earth can be accomplished with accuracy if enough observations can be made. Calculation of exact transfer ellipses between orbits has been carried out only for simple cases; but solution of the intercept problem will require exactly this. If basic information on the orbit of the target is available from the Earth, closure must still be accomplished by the vehicle, at least in its finer aspects. Precise directing of rocket thrust by pointing the vehicle not only requires accurate and stable references, but also cannot depend on complete control from hundreds of miles away. Techniques have been discussed, systems are being constructed, but a major problem area still exists in space navigation for predesignated orbits or intercept.

Data Processing

In addition to data processing equipment for navigation, added capacity should be available for other purposes, such as environmental control, recording of data, etc. The successes recently attained in packaging digital computers in extremely small sizes indicate that only adaptation and optimal exploitation of known techniques will be required.

Re-Entry

So much has been written regarding re-entry that it is unnecessary to discuss it in detail.[9, 10] The problem remains that of opening up a corridor within which the vehicle can fly without exceeding temperature and de-

celeration limits. Whether cooled surfaces, double-wall construction, ablation, or heat resistant structure carries the load of widening the corridor, or properties of all are used, is a matter of design concept and technical courage. At present, a double-wall structure, in which the outer skin is at high temperature, and therefore radiates efficiently, and an inner skin is cooled, seems capable of permitting sufficient flexibility along the re-entry trajectory.

Additional properties of the atmosphere on Mars and Venus will be desirable before entry there can be attempted. This can be attained through unmanned probes or by manned vehicles skirting those planets with enough energy to break away back to Earth. Although we do not understand all details of re-entry into our own atmosphere, enough information is at hand to try.

Conclusions

The appropriate and eventual space application for rocket vehicles is believed to be a manned space glider. Essential characteristics are:

(1) Reaction controls for attitude and vehicle thrust orientation.

(2) A rocket engine with thrust in excess of weight for safety during launch and boost, and for orbit size and plane changes.

(3) An appropriate environment in which a crew can accomplish significant tasks and obtain significant information.

(4) Use of aerodynamic forces during the critical and repetitive phase of re-entry and landing.

(5) A goal of maneuverability in space for whatever purpose it may be used—in particular, the capability for interception of satellites.

Such a vehicle not only fulfills many of the dreams of space enthusiasts, but actually is feasible in light of the technological stature we have attained.

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✦ ✦ ✦

Engineering and Science in Space (Continued from page 37)

there is a flow of information from science, but, in turn, the engineer offers capability in full measure to the scientist to do new things in his field, and often the impetus given by the engineer to the work of the scientist is the key pressure to keep the scientific work going.

In the Institute of the Aeronautical Sciences this close relationship between engineer and scientist has always been recognized and fostered. In fact, we aerospace engineers are fortunate that, from the beginning in the balloon age, through the years of manned and unmanned flight, and now into the space era, the engineering in our field has had this close relationship with science, giving to science new capability in return for new knowledge and at the same time offering our society the worth-while products of our profession.

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The concept of establishing a standard lineal deviation sensitivity, at a specified point on the approach, for aircraft localizer guidance systems at all instrumented airports is given. The operational advantages accruing from this standardization are outlined.

A statistical treatment of the system errors is presented, and, finally, an equation is derived which permits evaluation of the lateral guidance system performance.

Performance Criteria for

Aircraft Localizer Guidance Systems

During the Low Approach

Cecil C. Pine, MIAS

Sperry Phoenix Company

THE LOCALIZER guidance system is a valuable aid in landing modern transport and military aircraft under conditions of low visibility. This system consists of a radio beam aligned with the extended centerline of the runway which permits the determination of the aircrafts' position relative to the beam center during the approach.

The signals from the localizer beam can provide a displacement voltage to an automatic pilot for controlled guidance of the aircraft to the runway, thus relieving the human pilot of the arduous task of physically maneuvering the plane during this critical period.

Operationally, the use of the localizer beam for lateral guidance is a compromise between technical limitation and guidance requirements. Ideally, both the human pilot and the automatic pilot would like to know position with respect to the center of the beam in terms of a *distance* deviation; whereas the beam, because of its diverging characteristic, provides *angular* deviation information. Optimum effectiveness of the system can be achieved, however, by adjusting the system parameters to provide a standard distance or lineal deviation sensitivity at a specific point along the approach path for all localizer sites.

Careful appraisal of all components of the localizer guidance system, including site configuration parameters, must be made in order to achieve a specified standard at all sites. The adjustment tolerances of the system components must be examined to determine the most economical means of providing the standard, and the system errors must be evaluated to ensure a given probability of operational uniformity.

Establishing a Standard

The concept of establishing a standard lineal deviation sensitivity at a specified position along the final approach path for all localizer sites has been accepted generally. This standardization provides two operational advantages for aircraft guidance during the automatic approach:

(1) With a standard deviation sensitivity in microamperes per foot established at a fixed point near the runway threshold, it is possible to adjust all automatic pilots for optimum coupling performance at this point.

(2) The establishment of a standard lineal deviation sensitivity permits the human pilot to use the localizer deviation indicator as a go-no-go gage for purposes of estimating his probability of landing on the runway.

These two operational factors are extremely important when consideration is given to landing an aircraft in weather where it is necessary to descend to a low elevation before visual guidance is obtained.

Consider an aircraft making an ILS instrument approach with an automatic pilot. The job of the human pilot is to monitor the approach and either to land the aircraft when visual guidance is obtained or to initiate a missed approach maneuver. Lateral position is of extreme importance during the final approach since, without a definite clue as to this measurement, the

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pilot might "break out" and find he is unable to maneuver the craft to a landing on the runway.

If the pilot could use the localizer deviation indicator as a measuring device such that a definite limit on the meter would indicate a finite probability of being over the runway when he passed the threshold, he could assess the approach as to its success. That is to say, if the indication was below the specified limit, he would be ensured of a high probability of landing straight in on the runway. If the indication was beyond the limit, his probability of landing on the runway would be less than the accepted value and he would be justified in initiating a go-around.

The Yardstick

Let us visualize the localizer deviation indicator as a measuring device, a yardstick of sorts. The length of this yardstick is taken as the chosen limit value in microamperes on the indicator, divided by the beam sensitivity in microamperes per foot at the specified point along the approach. This limit is represented to the pilot by a red line on the localizer deviation indicator.

Normally, this yardstick will measure the distance between the centerline of the runway and the centerline of the aircraft *provided* the point at which the measurement is started is actually at the physical runway centerline. However, there are factors which influence the determination of exact centerline of the runway as measured by the localizer deviation indicator:

(1) Localizer beam misalignment.

(2) Aircraft receiver centering misalignment.

(3) Null width of the system which includes localizer bends and coupler dead zone.

There are certain other factors that influence the length of the yardstick which must be considered if the measurement is to have a significant meaning:

(1) The variation in the deviation sensitivity due to transmitter variations.

(2) The variation in deviation sensitivity due to receiver variations.

(3) The accuracy with which the pilot can read the exact limit value on the localizer deviation indicator.

To equate the foregoing values, let

B = nominal length of yardstick, ft. (not subject to statistical variation)
ΔB = error in length of yardstick
C = variation in beam center alignment, ft.
D = variation in receiver centering, ft.
E = variation in null width, ft.
F = variation in length of yardstick due to variations in transmitter beam sensitivity
G = variation in length of yardstick due to variations in localizer receiver sensitivity
H = variation in length of yardstick due to inaccuracy of reading limit value on localizer indicator

Assuming that the variables C, D, E, F, G, and H can be either plus or minus values; then the absolute *error* in the length of B can be expressed as

$$\Delta B = \pm C \pm D \pm E \pm F \pm G \pm H \qquad (1)$$

If the values of C, D, E, F, G, and H are considered to be random in nature for any given approach, and they approximate a normal distribution, then the determination of ΔB can be solved by statistical methods (see Appendix) and we can write

$$\Delta B = \pm [C^2 + D^2 + E^2 + F^2 + G^2 + H^2]^{1/2} \qquad (2)$$

Now, if we let A represent the *maximum* distance measured by B (considering the probability of errors in B), we may write

$$A = B + [C^2 + D^2 + E^2 + G^2 + H^2]^{1/2} \qquad (3)$$

where A will have the same probability factor as the terms in the brackets.

Discussion

Let us examine the significance of Eq. (3). The value of B is the nominal length of the yardstick as indicated by the red line on the localizer deviation indicator. The distance A we want to measure is the distance from the centerline of the runway to the outside wheel of the aircraft when it is on the edge of the runway. The statistical accumulation of tolerances tend to vary the length of the indicated distance B; therefore, it is necessary to choose the pessimistic case of plus tolerances to ensure with a high probability factor that the aircraft wheels will be over the runway when the localizer indicator reading is at or less than the red line value. Obviously, the wheel span varies with different aircraft, and runway widths vary at different sites. In order to achieve standardization, these values must be specified. The most predominant runway width of those sites considered and the span of the largest operating aircraft could be selected as the standard. This would mean that operation into airports with runways less than the selected width could not be guided by the standardization criteria, and higher weather minimum might be required at these sites. Aircraft with a narrower wheel span would have a probability advantage over those with the wider span. The overall tolerance of the system must be maintained within specified limits if standardization is to be achieved. Through the use of Eq. (3) and the expansions given in the Appendix, an evaluation of the individual tolerances can be made to determine the trade-off among them which will result in the most economical means of assuring the required system performance.

Since runway lengths vary from airport to airport, the localizer angular beam sensitivity must be adjusted accordingly to provide a standard lineal sensitivity at all sites. The use of equations given in the Appendix permits one to determine limits over which the localizer transmitter must be adjusted at various sites to maintain the standard. These limits can be compared with the operating limits of the present equipment to evaluate its adequacy or to predict necessary modifications.

There will be times when the indication on the meter will dictate the initiation of a missed approach procedure when, in actual fact, the pilot could have landed straight in. This is the price one must pay to be sure

of a high probability of success when using a system that is less than perfect.

Conclusion

Standardization of localizer guidance systems will provide an improved uniformity of automatic coupler performance at all airports equipped with instrument landing systems. It will also give the pilot a more accurate tool with which to determine his lateral displacement at the runway threshold.

The foregoing statistical analysis permits those responsible for implementing the localizer system standardization to appraise the components of the system and to determine the extent to which standardization can be achieved with present equipment and site configurations. Through a study of the system errors, as presented in this analysis, a prediction of operational uniformity based on a given probability factor can be made.

The techniques presented can be applied to the study and evaluation of any system in which the statistical accumulation of errors is an important factor in determining performance.

Appendix

Measurements of any system may be presented in the form $Y \pm \delta Y$, where Y is the best estimate of the true measurement, and δY is the best estimate of the error in Y based upon a given probability factor.

When several independent errors in a system are combined, it may be shown that

$$\delta Y_z = [\sum_{i=j}^{p} (\partial Y/\partial X_i)^2 \delta X_i^2]^{1/2} \qquad \text{(A-1)}$$

where Y = any differential function of the observed quantities X_i, and δX_i = the best estimate of the error in X_i.

The validity of the Eq. (A-1) is based upon the premise that the errors are small with respect to the measured value and that they approximate a normal distribution.

When X_i is an observed value of Y, then $\partial Y/\partial X_i$ reduces to 1 and Eq. (2) may be written

$$\delta Y_z = [\sum_{i=j}^{p} \delta X_i^2]^{1/2} \qquad \text{(A-2)}$$

Substituting ΔB—see Eq. (1)—for δY_z and the errors C through H for $X_{j,\,k,\,l,\,m,\,n,\,p}$ we may write

$$\Delta B = \pm [C^2 + D^2 + E^2 + F^2 + G^2 + H^2]^{1/2} \qquad \text{(A-3)}$$

Now if we let A represent the *maximum* distance measured by B (considering the probability of errors in B), we may write

$$A = B + [C^2 + D^2 + E^2 + F^2 + G^2 + H^2]^{1/2} \qquad \text{(A-4)}$$

where A will have the same probability factor as the terms in the brackets.

By squaring both sides, Eq. (A-4) can be expanded to

$$A^2 - 2AB + B^2 = C^2 + D^2 + E^2 + F^2 + G^2 + H^2 \qquad \text{(A-5)}$$

We have chosen to solve the equation for lineal deviation sensitivity since this is the one parameter that can be adjusted most easily in the field. To do this, we must evaluate all of the terms in Eq. (A-5), particularly those containing deviation sensitivity which will be designated by ρ_f:

Let $A = (R - W)/2$ (maximum distance off center and still have wheels on the runway), where R = runway width, and W = aircraft wheel span.

Let $B = N/\rho_f$ (nominal length of yardstick), where N = go-no-go limit, microamp. (red line on localizer deviation indicator), and ρ_f = lineal deviation sensitivity, microamp./ft.

Let $C = \delta\theta_{tm}S$, where $\delta\theta_{tm}$ = transmitter misalignment, rad., and S = distance of specified point along approach path from transmitter.

Let $D = \delta I_c/\rho_f$, where δI_c = receiver centering error, microamp.

Let $E = \delta f$, where δf = maximum null width at threshold, ft.

Let $F = (\delta\theta/\theta)\cdot(N/\rho_f)$, where $\delta\theta$ = transmitter beam width error, and θ = transmitter beam width.

Let $G = (\delta I_R/I_R)\cdot(N/\rho_f)$, where δI_R = error in receiver microamperes at arbitrary test point, and I_R = receiver microamperes at arbitrary test point.

Let $H = \delta I_m/\rho_f$, where I_m = error in microamperes in reading limit current N on indicator.

If these symbols are substituted in Eq. (A-5), we may then proceed to solve for ρ_f:

$$\frac{1}{\rho_f^2}\left[N^2 - \delta I_c^2 - \left(\frac{\delta\theta}{\theta}\right)^2 N^2 - \left(\frac{\delta I_R}{I_R}\right)^2 N^2 - \delta I_m^2\right] - \frac{(R - W)N}{\rho_f} + \frac{(R - W)^2}{4} - (\delta\theta_{tm}S)^2 - \delta f^2 = 0 \qquad \text{(A-6)}$$

Let $a = \left[N^2 - \delta I_c^2 - \left(\frac{\delta\theta}{\theta}\right)^2 N^2 - \left(\frac{\delta I_R}{I_R}\right)^2 N^2 - \delta I_m^2\right]$

$b = (R - W)N$

$c = [(R - W)^2/4] - (\delta\theta_{tm}S)^2 - \delta f^2$

Solving the quadratic, we have

$$1/\rho_f = [-b \pm (b^2 - 4ac)^{1/2}]/2a \qquad \text{(A-7)}$$

Now it is possible to insert the numerical values of all the variables, such as runway width, receiver and transmitter errors, etc., and to determine the lineal deviation sensitivity to meet the requirement that the aircraft will have a given probability of being over the runway if the limit as read on the indicator is not exceeded.

In order to determine the localizer beam width to give the desired value of ρ_f, at the specified point in the approach zone, we may write

(*Continued on page 66*)

Should the Laws of Gravitation Be Reconsidered?

Part I—Abnormalities in the Motion of a Paraconical Pendulum on an Anisotropic Support

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Whenever a physical theory is revised or transformed, it is revealed that, nearly always, the observation of one or several facts which could not fit within the framework of the theory in its then current form is at the base of the changes. The facts always remain the keystone on which the stability of any theory is dependent, no matter how important it may be.

For a theoretician really worthy of the name, it may be said in passing that nothing could be more interesting than a fact which runs counter to a theory until then held to be sound; for him, the real work begins at that point.

Max Planck[1]

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THE MOTIONS of a pendulum, suspended on a ball and resting on an anisotropic support, have statistically significant amplitude and periodic components of periods approaching 24 and 25 hours.

The installation and the experimental technique are briefly described. The observed motions result from four conjugate effects: the Foucault effect, an effect of the suspension release, the aleatory influence of balls, and, finally, a periodic influence.

The observed periodic structure cannot be considered as due to the disturbances of an aleatory order. Neither can it be considered as produced by an indirect influence of known factors (temperature, pressure, magnetism, etc.). Finally, it cannot be identified with periodic lunisolar effects resulting from the actual theory of gravitation.

A remarkable disturbance has also been observed at the time of the total solar eclipse—June 30, 1954.

At this stage of the discussion, the observed effects must be considered as produced by the direct action of a new field.

Findings

From 1953 to 1957, I carried out various experimental research projects on the motion of a pendulum resting *on an anisotropic support* S″ through a steel ball, this anisotropic support being characterized by very small differences in its elasticity as measured in two rectangular planes.[2]

Even though various types of pendulum were used in succession, I shall limit myself to a brief description of the arrangements used and the results obtained during the series of continuous observations which were run for 30 days in June and July of 1955.

Description of the Pendulum

The paraconical pendulum used was an asymmetrical one, consisting of a vertical bronze disc weighing 7.5 kg., attached to a bronze rod hung from a bronze stirrup E resting on a steel ball 6.5 mm. in diameter, free to roll in any direction on a horizontal plane surface S.

The latter was itself on a hollowed-out circular support S′, made of aluminum, with an extension A, 4.5 cm. thick. This design (hollowed-out part) made it possible for the pendulum to rotate while in motion, over a total angle of 210 centesimal deg. This circular support S′ finally rested on three micrometric screws V. The pendulum rod and its stirrup weighed 4.5 kg. so that the total weight of the pendulum was 12 kg. and the length of the equivalent elementary pendulum approximately 83 cm.

The steel balls in use were high-precision SKF balls, with bearing surfaces of tungsten carbide and cobalt.

The experiments were conducted in a basement, and the center of gravity of the pendulum was moving at a level of approximately 1.50 m. below the surface of the natural ground. Support S″ was bolted to a beam, pressed against the ceiling by a set of beams.

The pendulum and hanging device are shown in Figs. 1 to 4.

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[1] *Initiation to Physics*, French transl., page 40; Flammarion, Paris.

[2] My findings and the investigations to which they gave rise are dealt with in six notes of the Academy of Sciences: C.R.A.S., 245, 1697; C.R.A.S., 245, 1875; C.R.A.S., 245, 2001; C.R.A.S., 244, 2469; C.R.A.S., 245, 2467; C.R.A.S., 245, 2170. The reader may refer to these for useful data which cannot be quoted here for lack of space. The object of the present paper is to reveal only the general philosophy of the results achieved. It is but an abstract of a general report which will be published shortly.

In Part I we propose to review, in an extremely cursory manner

(a) *the abnormalities observed in the motion of a paraconical pendulum (pendulum hanging from a steel ball) on an anisotropic support.*

(b) *the manner in which they should be interpreted, according to the present status of our information and discussions.*

In Part II (to be published in the October issue), we shall point out the relationship that these abnormalities appear to have with the irregularities or abnormalities noted when investigating a number of phenomena in the realms of mechanics, optics, and electromagnetism.

Experimental Process

The pendulum was released from a resting position every 20 min., using an initial amplitude of about 0.11 radian, by the burning of a thread. Its motion was then observed for about 14 min. by aiming at a needle attached to its lower extremity.

Generally speaking, the point so observed generated a curve comparable to a flattened ellipse, the plane of the major axis of which was observed with an aiming system placed on a circle C centered on the axis of the pendulum as defined at rest, and equipped with a scale graduated in centesimal degrees and a vernier. This system made it possible to determine the azimuth of the plane of oscillation with a precision of about 0.1 centesimal deg.

After 14 min., the pendulum was stopped, and it was again released in the plane of the last observed azimuth. Thus the successive series of observations were *connected*, with releases every 20 min., day and night, so that each 24-hour period was made up of 72 series of connected azimuth observations.

In order to rule out any systematic effect, the steel ball which carried the pendulum was changed after *each experiment*, every 20 min., and surface S was changed at the beginning of each week of observations.

A curve showing the azimuths observed from June 7 to 12, 1955, is given in Fig. 5. Each point represents the release azimuth corresponding to each series of 14-min. observations, equal to the azimuth of the plane of oscillation established after 14 min. in the above experiment.

Anisotropy of the Support

Since support S″ was characterized by a very *small* difference in its elasticity values in two rectangular planes, the mean position of the plane of oscillation tended, under this influence, to locate itself parallel to the plane of greatest elasticity of the support indicated by vector $\overrightarrow{PQ}$ in Figs. 1 and 3, the azimuth of which was approximately 171 centesimal deg., measuring azimuths from the south in the direct sense. Here again, *the overall tendency was to generate ellipses* when the pendulum was released in a plane other than $\overrightarrow{PQ}$. These influences were determined more accurately by releasing experiments in various azimuths, in eliminating the influence of the epoch with a random choice of the release azimuths.

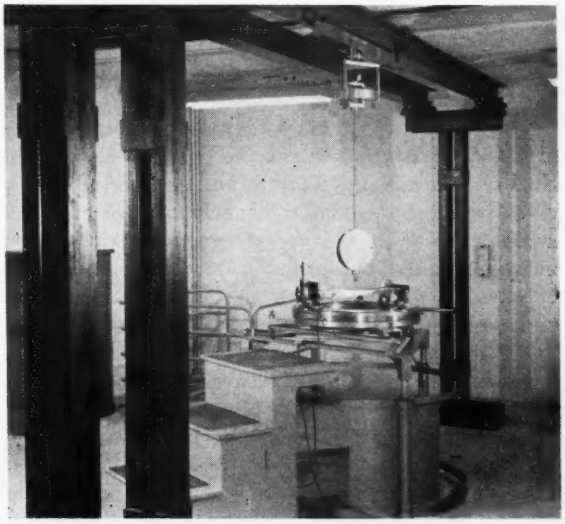

Fig. 1. General view.

Fig. 2. Measuring circle.

Observed Phenomena

During a continuous series of observations, however, the oscillating plane had not evinced any tendency to settle in the vicinity of direction PQ, as might have been expected—allowing for the Foucault effect—and the variation of the azimuth as a function of time was found to be an oscillation which appeared to be very irregular, at least at first glance, about the mean direction PQ′. The deviations observed over a given 24-hour period were very large; azimuth variations occasionally reached and exceeded 100 centesimal deg. The mean observed azimuth P′Q′, as a matter of fact, was 150 centesimal deg. on June–July, 1955, less than the azimuth of PQ by 22 centesimal deg.

It is noteworthy that the tangent to the start of the mean of the various curves that correspond to the 2160 series of 14-min. elementary observations making up the monthly series for June–July, 1955, is an accurate representation of the Foucault effect.

Factors Influencing the Motion

In the *present* condition of my information, it may be assumed that the observed azimuth movements are the result of four conjugated effects: the Foucault effect, a "return" effect due to the suspension, the random influence of the spherical ball, and, finally, a periodic effect.

This periodic effect, which constitutes the very striking aspect of the phenomenon reviewed, was revealed, in the time series made up of the azimuths observed over a given period, by a number of techniques of harmonic analysis, the results of which were in remarkable agreement: Buys-Ballot filter, adjustment to a given group of waves by the Darwin or the least square method, periodogram, and correlogram.

Fig. 6 shows the adjustment graph obtained by the application of the Buys-Ballot method to the June–July, 1955, series for the 25-hour wave.

Defining Σ as the typical deviation of the time series made up of the values of the azimuths observed and R as the radius of the wave which corresponds to the analysis made with a Buys-Ballot filter, we give (in Table 1) the results obtained for the series of observations of June–July, 1955:

Order of Magnitude of Effects Noted

The azimuth rates which correspond to the amplitudes of the two major periodic components revealed in the June–July, 1955, series—the periods of which are close, respectively, to 24 and 25 hours—are each of an order of magnitude equal to one-tenth of the Foucault effect. However, the disturbing influences noted are, on an average and as a whole, about twice the Foucault effect.

Table 1.

Σ	$2R$		R_{25^H}/R_{24^H}	R/Σ	
	24^H	25^H		24^H	25^H
19.99	11.66	14.01	1.20	0.29	0.35

The values are given in centesimal degrees.

Abnormality Noted During Total Solar Eclipse

Let us point out, finally, that an abnormal lunar and solar influence also became apparent in the form of a remarkable disturbance of the motions of the paraconical pendulum (which gave the very definite impression of a screen effect) during the total solar eclipse of June 30, 1954. The plane of oscillation of the paraconical pendulum shifted approximately 15 centesimal deg. during the eclipse (see Fig. 7).[3] The forces involved were of the same order of magnitude as those which correspond to the Foucault effect.

Here, reduced to essentials, are the facts noted to date.

Four Basic Questions

The interpretation of the experimental results leads to the following four basic questions, to be raised in the order given.

First Question

Do the monthly series of observations contain statistically significant periodic terms, with periods in the vicinity of 24 and 25 hours?

[3] Fig. 7 shows an azimuth curve tracing for the period extending from June 28, 1954 (8 p.m.), to July 1, 1954 (4 p.m.), as well as a curve symmetrical to the left part of the curve, which represents the azimuth referred to, about the vertical straight line for June 30 (midnight). Just at the beginning of the eclipse, the azimuth of the plane of oscillation suddenly was raised 5 centesimal deg. above the trend which first characterized its motion. Twenty minutes before the maximum of the eclipse, which was recorded at 12:40, this deviation reached a maximum of 15 centesimal deg. and then decreased progressively—but more suddenly than it had increased. The deviation was no more than 1.20 centesimal deg. prior to the end of the eclipse.

It will be noted that, to such an extent as may be ascertained, the shift of the plane of oscillation resumed, after the eclipse, the appearance of a motion CD, analogous to AB, which had been noted prior to the said eclipse (Fig. 7b).

Fig. 7a reveals an approximate symmetry of the azimuth curve with respect to the vertical for June 30, at 12 midnight. This symmetry, which can be ascribed to the periodic structure of the motion, is noted for approximately 28 hours. If we assume, as is likely, that this symmetry corresponds to a physical reality independent of the disturbances created by the contact between the steel ball and the surface, it is notable that nothing in the branch of the azimuth curve which precedes the time corresponding to the center of symmetry is in any way comparable to the very strong deviation noted during the eclipse.

It must be further underscored that, during all continuous observation periods, no variation of the azimuth curve similar to branch BC, corresponding to the solar eclipse of June 30, 1954, was ever observed.

It should be noted that the maximum deviation due to the eclipse took place 20 min. prior to the maximum of the eclipse. Thus there is a measure of dissymmetry in the effect noted. A similar dissymmetry has been observed for terrestrial magnetism, but in the opposite direction, the maximum of the effect having been observed after the maximum of the eclipse. (Lion, C.R.A.S., 1851, T. 33, p. 202; Lion, C.R.A.S., 1852, T. 34, p. 207; Lion and Muller, C.R.A.S., 1874, T. 74, p. 199. For the terrestrial electric field: Nordmann, C.R.A.S., January, 1906, p. 40; Chevrier, C.R.A.S., 1933, T. 197, p. 1143; Rouch, C.R.A.S., 1954, T. 239, p. 465.)

Second Question

If so, can the periodic effects so noted be identified with those due to the current theory of gravitation (as derived from the double principle of inertia and universal gravitation, which is assumed to apply with respect to the whole set of Galilean frames of reference) as complemented (possibly) by corrections derived from the theory of relativity, and such as this current theory of gravitation is applied within the framework of the current theory of relative motions?

Third Question

If not, can the existence of periodic terms which are of significance in the series so obtained be ascribed to an indirect influence of a known periodic phenomenon, specifically, to one of the following phenomena:

(1) Deviation of the vertical (terrestrial tides).
(2) Variation in the intensity of gravity.
(3) Thermal effect:
  (a) General (temperature at Le Bourget).[4]
  (b) Local (laboratory temperature).

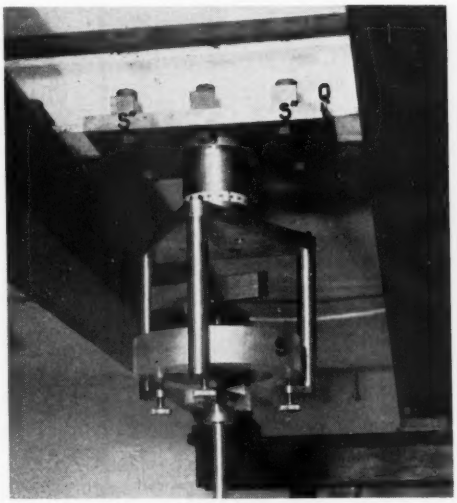

Fig. 3. Suspension.

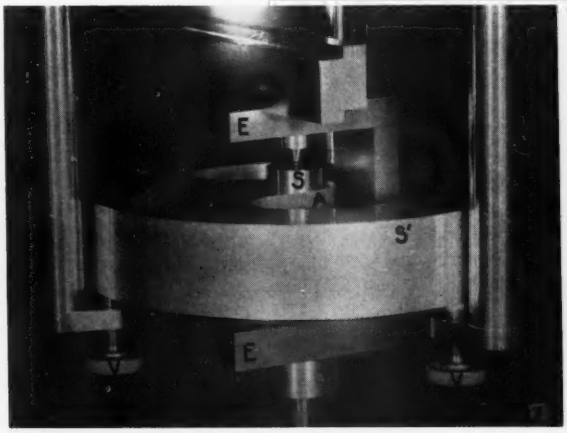

Fig. 4. Detail of suspension.

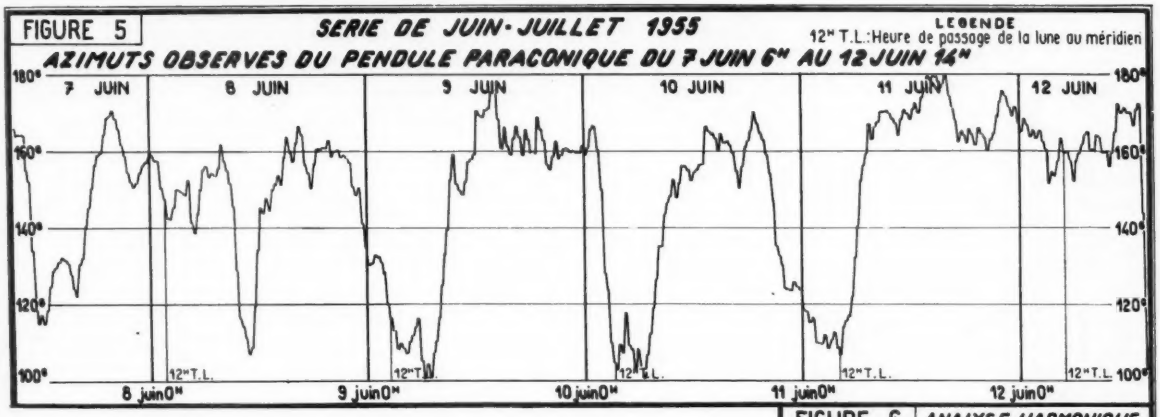

Fig. 5 (above). Series for June–July, 1955. Azimuths of the paraconical pendulum observed from June 7, 6:00 a.m., to June 12, 2:00 p.m.

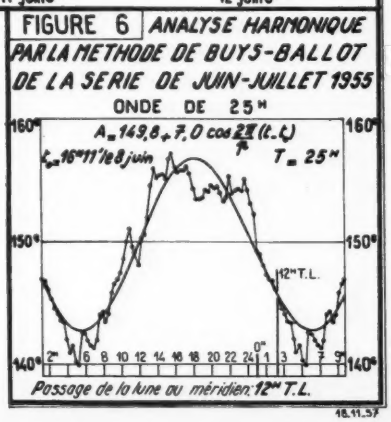

Fig. 6 (*right*). Harmonic analysis of the June–July, 1955, series, using the Buys-Ballot method.

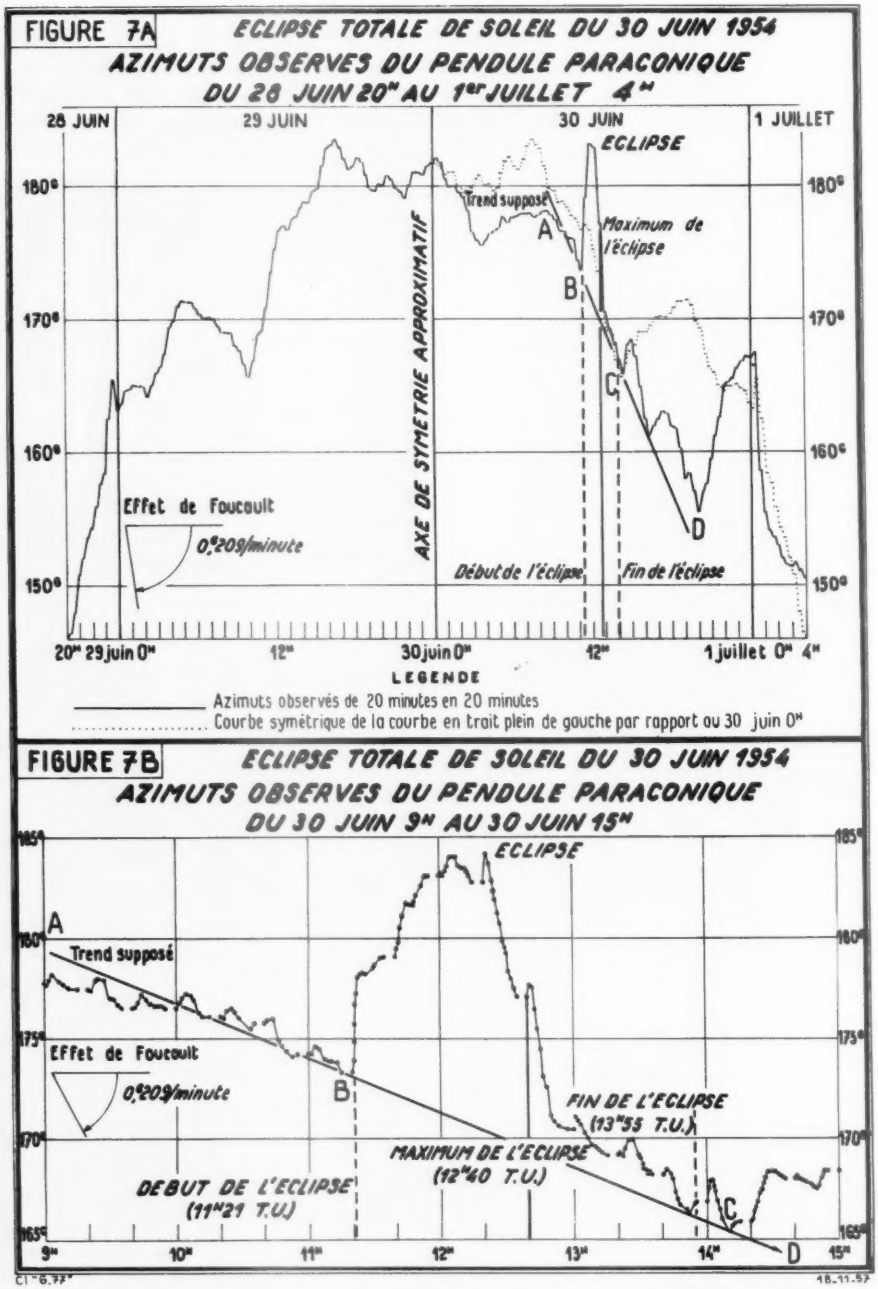

Fig. 7a (top). Total solar eclipse, June 30, 1954. Azimuths of the paraconical pendulum observed from June 28, 8:00 p.m., to July 1, 4:00 a.m. Fig. 7b (bottom). Total solar eclipse, June 30, 1954. Azimuths of the paraconical pendulum observed from June 30, 9:00 a.m., to June 30, 3:00 p.m.

(4) Barometric effect:
  (a) General (pressure at Le Bourget).
  (b) Local (pressure in the laboratory).
(5) Magnetic effect:
  (a) Normal effect (terrestrial magnetic field as recorded at Chambon la Foret).[4]
  (b) Magnetic agitation (K numbers of Bartels).
(6) Microseismic agitation:
  (a) Industrial microseisms.
  (b) Wind effects.
  (c) General microseismic agitation.
(7) Cosmic rays.
(8) Periodic character of human activity.
(9) Periodic modification of the structure of the device.

Fourth Question

If a negative answer to the third question is in order—namely, if we must conclude that the effects noted are due to the direct action of a new field—should the origin of this field be assumed to be solar, lunar, lunar and solar, or spatial?[5]

Answers to the Four Basic Questions

Answer to the First Question

Any discrete series of $2n + 1$ numbers may be represented by the sum of a constant and n sine waves.

The obtaining of a sine wave of a given period by any method of harmonic analysis can therefore be of real significance only if its radius is sufficiently large and if the periodic structure noted is found again in the various elementary periods into which the period of observation under review can be broken down.

(a) The generalization of the Schuster test[6] leads to the conclusion that, for the two monthly series of November-December, 1954, and June-July, 1955, the amplitudes of the waves (or groups of waves) which have periods close to 24 and 25 hours must each be considered to be very significant statistically (the significance level is at least 10^{-4}).

(b) The periodic structure of the monthly series must be considered to hold for the two periods of one fortnight, and even for the periods of one week, into which each one-month series can be broken down, for the following reason:

Simultaneous analysis, by the method of the least squares, for 13 waves of the tide series, gives 13 sine curves, the sum of which can be found with the help of Lord Kelvin's tide predictor. The calculated series so obtained, *which is the sum of the 13-sine curve*, can be analyzed, for 24 and 25 hours, by the same method of the Buys-Ballot filter.

[4] Observatory nearest my Saint-Germain laboratory.

[5] By this, I mean a field which could not be related to the sun or to the moon. This could be, for instance, a field resulting from a dissymmetry of the inertial sidereal space. A possible period would then be 24 sidereal hours.

[6] See footnote 2.

Table 2.

Series	Values H-H′ June-July, 1955	
	24^H	25^H
$1+2+3+4$	0^H06^{mn}	0^H02^{mn}
$1+2$	-1^H09^m	0^H02^m
$3+4$	$+0^H43^{mn}$	$+0^H15^{mn}$
1	-1^H08^m	-0^H33^m
2	$+0^H59^{mn}$	$+2^H20^{mn}$
3	-1^H23^{mn}	-0^H56^{mn}
4	$+0^H59^{mn}$	$+0^H57^{mn}$

If the sine curves obtained *really* exist in the raw series, the Buys-Ballot method must give, for each elementary period, a sine curve having phases that are comparable for both the crude and the computed series. Table 2 shows the results obtained for the value *H-H′* representing the difference between those two phases in hours and minutes, for the series of June-July, 1955.

Notation 1 represents the first week; notation $1 + 2$ represents the first 2 weeks, and $1 + 2 + 3 + 4$ represents the whole of the month.

Allowing for the fact that each week can be considered an independent experiment, such agreement between the phases must be deemed to reveal the existence of true periodicity. This leads us to the conclusion that the monthly series of June-July, 1955, *actually* contains periodic elements with periods close to 24 and 25 hours.

Thus the answer to the first question must be "yes" in all certainty.[7]

Answer to the Second Question

The current theory of gravitation (being the result of the application, within the framework of the current theory of relative motions, of the principles of inertia and universal gravitation to any one of the Galilean spaces), complemented or not by the corrections suggested by the theory of relativity, leads to orders of magnitude for lunar and solar action (which are strictly not to be perceived experimentally) of some 100 millions of times less than the effects noted.[8]

These effects are so small that none of the nineteenth-century authors who worked on the theory of the pendulum, some of whom were excellent mathematicians, ever had a desire to compute them.

The extreme smallness of the effects computed can readily be accounted for if we allow for the fact that, in order to obtain the true gradient $\vec{f}$ of the moon and sun attraction at a point, on the surface of the ground, with respect to the earth, we must take the difference between the attractions at this point and at the center

[7] Much store has been set in the defects of the equipment used—imperfect steel balls, imperfect horizontal positioning of the support, etc. I cannot stress enough that the only possible effect of imperfections in the equipment are effects of a systematic or random type and that, under no circumstances, could they entail, whatever they be, the existence of any real periodicity.

[8] On the order of 10^{-13} instead of the periodic effects noted of some 10^{-5} rad. per sec.

XUM

Table 3.

	2R			
	25^H	24^H	12^H30	12^H
June-July, 1955	14.01	11.66	3.71	2.69

of the earth, respectively. Gradient $\vec{f}$ is of the order of 10^{-8}.

Furthermore, the plane of oscillation of the pendulum can rotate, under the influence of the solar and lunar attraction, only because of the variations of the gradient about the point considered. Therefore, the difference $\Delta\vec{f}$ between the value of $\vec{f}$ at the mean position of the pendulum and its magnitude at a nearby point must be considered. It[9] is of some 10^{-13}.

Furthermore, nothing in the current theory of gravitation can be considered likely to account for the screen phenomenon observed during 1954.

Therefore, the answer to the second question must be *no, and this in all certainty.*

Answer to the Third Question

The very peculiar periodic structure of the series observed (amplitude of the 25-hour wave of the same order of magnitude as that of the 24-hour wave and very much larger than the amplitude of the 12- and 12.5-hour wave) leads to the elimination, as possible causes of the observed abnormalities, of all the phenomena noted above under the order numbers 1 to 9. (Table 3 shows the results obtained for the series of June-July, 1955, the periodicity of which is significant.)

Indeed, for all these phenomena, the total of the amplitudes of the waves having periods close to 25 hours is small as compared to the total of the amplitudes of the diurnal solar wave group, the semidiurnal solar wave group, or the semidiurnal lunar wave group.[10, 11]

The answer to the third question therefore must be, for elements 1 to 9 as limitatively listed above, that the effects observed cannot be assumed to arise indirectly out of the action of any of these elements. This statement can be made *categorically.*

As long as a phenomenon other than those listed above has not been proposed as a possible explanation, it will be necessary to assume that the phenomena observed are due to the direct action of a new field.

Thus the answer given to the third question is a qualified one.[12]

Answer to the Fourth Question

If, in the present condition of the discussion, we must answer the third question with a hypothesis of the direct action of a new field, there will arise the question of determining whether this field is derived from the action of the moon, from that of the sun, from their conjugated action, or, again, from a spatial influence.

Two remarks are in order:

(a) In reviewing monthly series, there is no way of specifying, when a wave with a period of 24 hours is revealed, whether one is dealing with a solar or sidereal 24-hour period.

(b) Similarly, when dealing with a period close to 24 hours, 50 min., nothing justifies the claim that one is dealing with a lunar—rather than a solar—effect. The mean synodic rotation of the sun about its own axis is 27.275 mean days, whereas the sidereal revolution of the moon is 27.321 days. As for the mean solar day, it is very close in value to the mean sidereal day.

In order to reach a definite decision, it would be necessary to use far longer periods of observation.

Thus it appears to me that it is impossible to conclude with definite certainty that the periods revealed, of an order of magnitude equal to 24 and 25 hours, are derived respectively from a solar and a lunar action. *In the current status of available information,* such an action only appears to me as *very likely.*[13]

The answer given to the fourth question, therefore, has to be of the qualified type.

(This article will be concluded in the October issue. Part II will discuss experiments in connection with the abnormalities described in Part I.)

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[9] See the accurate expression of the effect in my paper to the Academy of Sciences (December 16, 1957).

[10] Thus, for instance, for the lunar and solar gravitational potential, the total of the amplitudes of the waves having periods of close to 24 hours is approximately 18 times greater than the total of the amplitudes of the waves with periods of close to 25 hours.

[11] Aside from the general argument of the specific periodic structure of the results obtained, which, of itself, is enough to rule out causes 1 to 9, a certain number of additional arguments may be presented, some of which are of considerable value and lead to the same conclusion but, for lack of space, are not presented here.

[12] I believe I should point out that nothing else can be the case. I can give my answer only with regard to the phenomena which I considered or which were suggested to me as being such as to account for the effect noted. It is quite possible that an explanatory phenomenon be propounded very soon which would definitely prove decisive when investigated. However, in the present condition of the discussion and allowing for all the factors already reviewed, the existence of such a phenomenon seems at least to be unlikely.

[13] The only known phenomenon related to the rotation of the sun is that of the spots. It really seems quite unlikely that the variations in the radiation due to the spots can have effects of an order of magnitude similar to that of the suppression of radiation during the night. As a matter of fact, there is no connection at all between the observed azimuths and the Wolf numbers, which are characteristic of lunar activity (for which, unfortunately, we have only one value per diem).

However, it cannot be claimed that there are no other effects related to solar rotation. This is enough to rule out a fully certain and unequivocal conclusion.

✦ ✦ ✦

This report adapts the principles of Libove and Hubka[1] to predict one of the elastic constants for the double "V" type of corrugated-core sandwich panel. The value of this constant represents the transverse shear stiffness of the panel. Formulas and charts for the evaluation of this constant are included, together with experimental data to substantiate the analysis.

Transverse Shear Stiffness

for the Double "V" Corrugated-Core Sandwich Panel

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Mr. Sapowith graduated from West Point in 1947 and received his Master's degree in Aeronautical Engineering from Purdue University in 1950. Assigned as an R&D officer at Wright Field, he studied the effects of blast loads from atomic weapons for over 3 years. He has since worked on dynamic and structural problems at Piasecki Aircraft Company and The Budd Company, both of Philadelphia. At Budd, he served as Project Engineer on the Minuteman. He has recently joined the staff of Allied Research Associates, Inc., Boston, as a Senior Engineer.

CONSIDER a section of a double "V" panel one pitch wide and of unit depth subjected to the following loads: a transverse shear Q_y and horizontal forces Y (Fig. 1). For small Q_y relative distortions of the element are proportional to Q_y. These relative distortions δ_y and δ_z are shown in Fig. 2. The average shear strain may be written as $\gamma_y = (\delta_y/h) - (\delta_z/p)$, and D_{Q_y} is then given by the ratio of shear intensity to shear strain or

$$D_{Q_y} = Q_y/\delta_y = 1/[(\delta_y/h) - (\delta_z/p)] \qquad (1)$$

As in reference 1, a free body diagram is drawn for the double "V" panel (Fig. 3), and the distortions of the elements are shown in Fig. 4.

Certain assumptions are made: (1) anticlastic curvature is completely restrained; (2) the forces of "Y" are considered as acting in the midplanes of the skins and transmitted to the corrugations through short rigid projections; (3) the moments M_1 are taken about points in the midplanes of the skins and are not the actual moments in the corrugations at points A, C, E, and G.

As a result of symmetry, all forces and deformations are equal for the four sections of corrugations and skins. Assuming the skin moments are zero at points B and F and the tangent at D remains fixed, the following equations can be written:

$$2X - 2Z_1 = 1 \qquad (2)$$

$$M_1 = -Z_1 p \qquad (3)$$

$$M = M_1 + Y\,[h_c + (t_s + t_c)/2 - v] - X(p - u) \qquad (4)$$

$$\phi = \frac{1}{E_c I_c/(1 - \mu_c^2)} \int_D^C M\, ds \qquad (5)$$

$$\delta_y = \frac{1}{E_c\, I_c/(1 - \mu_c^2)} \int_D^C M\, v\, ds \qquad (6)$$

$$\delta_z = -\frac{1}{E_c\, I_c/(1 - \mu_c^2)} \int_D^C M\, u\, ds \qquad (7)$$

$$\delta_z = \frac{Z_1 p^3}{3E_s\, I_s/(1 - \mu_s^2)} + p\phi \qquad (8)$$

Symbols

D_{Q_y}	=	transverse shear stiffness, lbs./in.
D_y	=	transverse bending stiffness per unit width, in.lbs.
E	=	modulus of elasticity, lbs./in.^{2}
h	=	centroidal distance between skins, in.
h_c	=	centerline height for single core element (Fig. 3), in.
I	=	moment of inertia, in.^{3}
M	=	bending-moment intensity, lbs.
p	=	one half core pitch, in.
P	=	load, lbs.
Q_y	=	shear intensity, lbs./in.
S	=	design coefficient in the formula for D_{Q_y}, $D_{Q_y} = S[E_c/(1 - \mu_c^2)]$, in.
t	=	thickness, in.
u	=	horizontal distance, in.
μ	=	Poisson's ratio
v	=	vertical distance, in.
ω	=	maximum deflection of beam (Fig. 7), in.
Y	=	horizontal force, lbs.
Z_1	=	skin shear, lbs.
δ_y	=	relative distortion in horizontal direction, in.
δ_z	=	relative distortion in vertical direction, in.
θ	=	core flat angle (Fig. 1), deg.
c	=	subscript for core
s	=	subscript for skin

The author wishes to acknowledge the cooperation of Dr Michael Watter of The Budd Company where this work was performed.

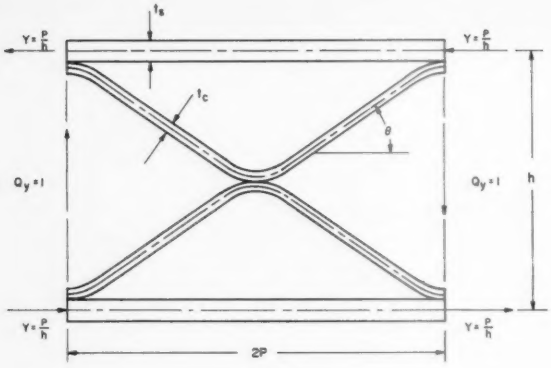


Fig. 1.

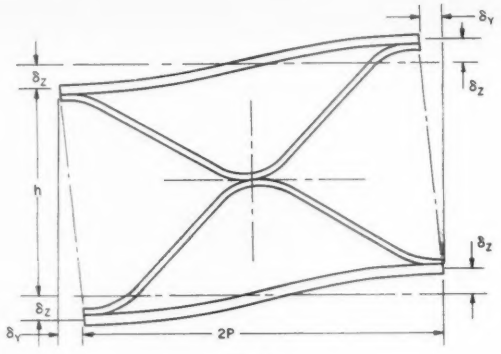


Fig. 2.

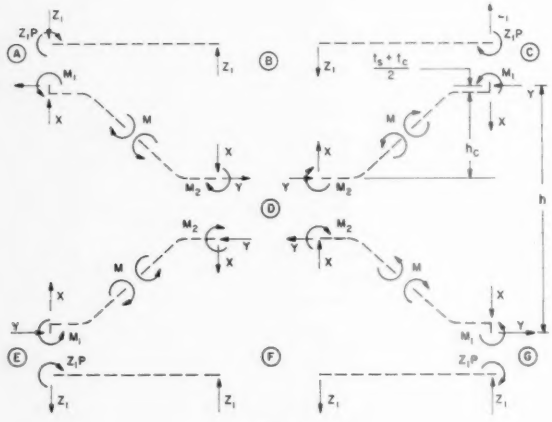


Fig. 3.

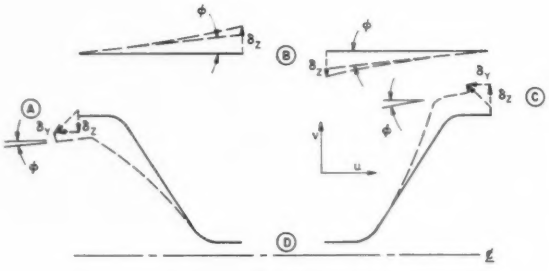


Fig. 4.

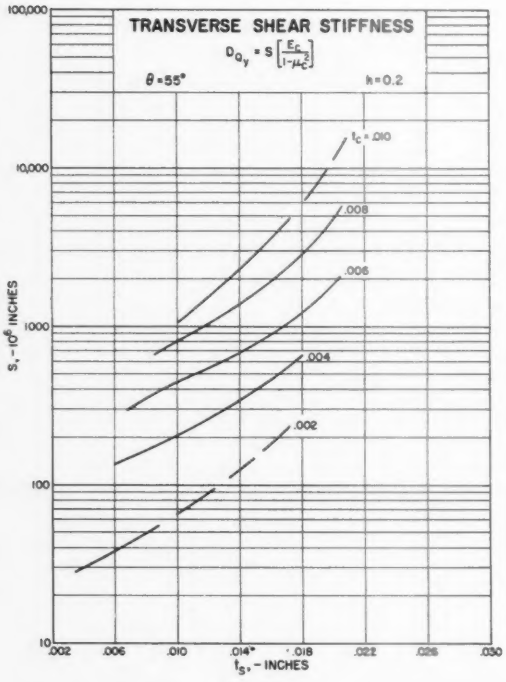


Fig. 5a.

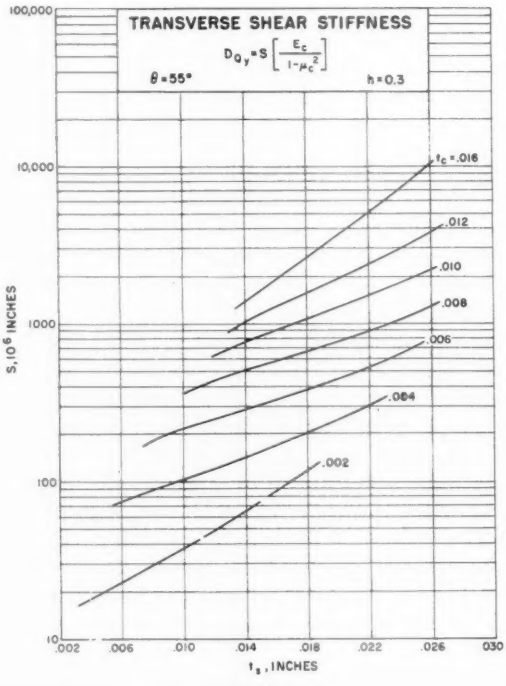


Fig. 5b.

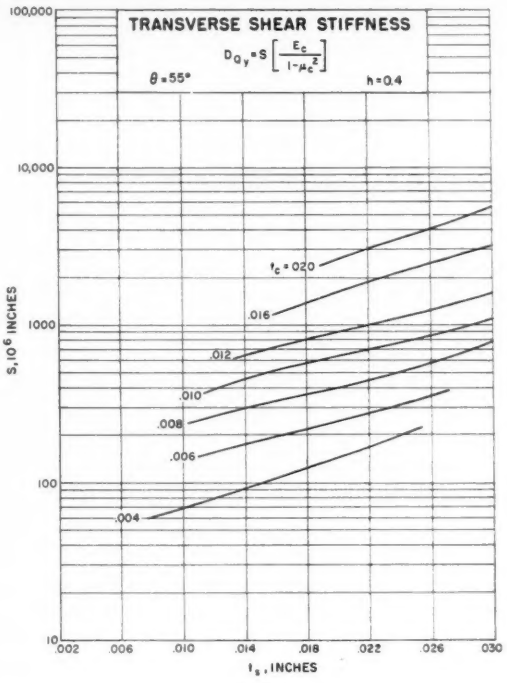


Fig. 5c.

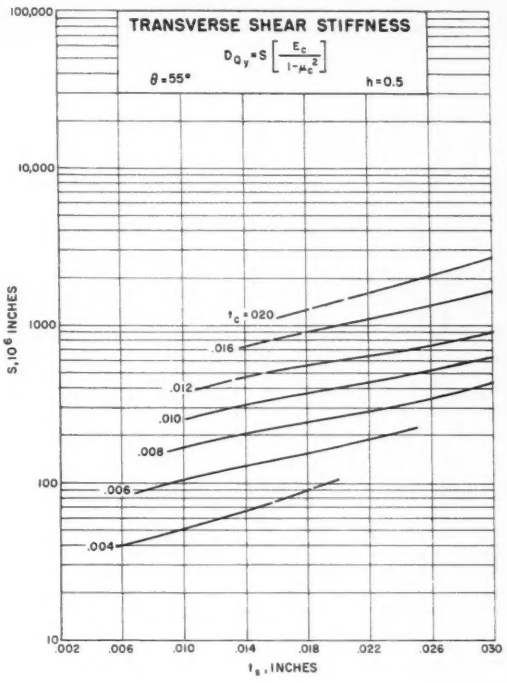


Fig. 5d.

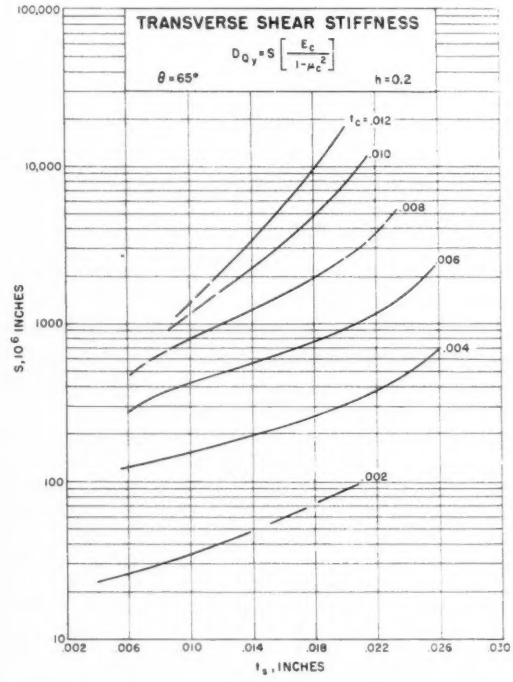


Fig. 6a.

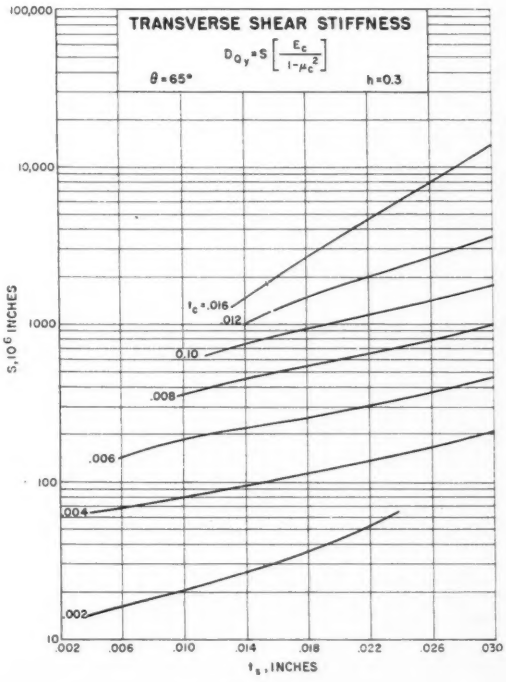


Fig. 6b.

XUM

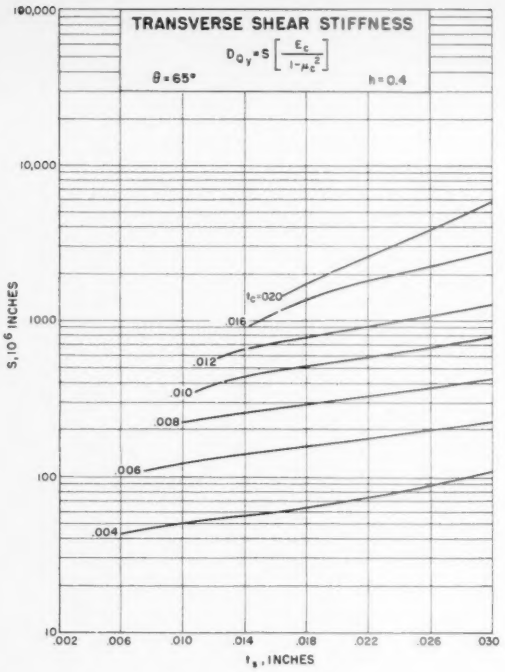
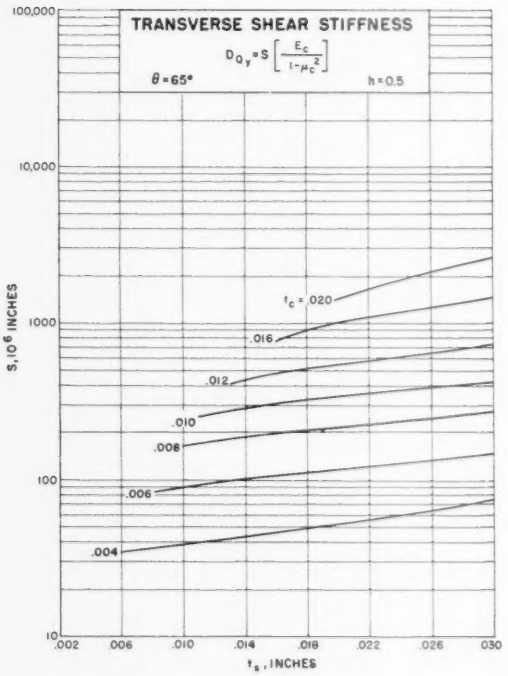


Fig. 6c.



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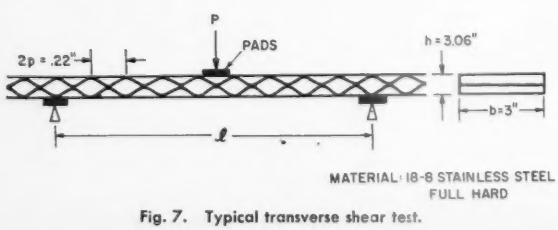

Fig. 7. Typical transverse shear test.

Table 1.

t_c	t_s	h_s	$2p$	θ	Theoretical D_{Q_y}	Test D_{Q_y}
0.006	0.014	0.306	0.220	67°	5,670	6,010
0.010	0.018	0.443	0.393	57°	11,590	10,900
0.008	0.016	0.309	0.218	67°	12,500	12,700

Eqs. (6) and (7) do not include the component of deflection due to stretching as does reference 1. The effect of this component on the value of D_{Q_y} proved to be less than 1 per cent of the total value for the panels considered.

The above equations may be solved for δ_y and δ_z from which D_{Q_y} may be determined. The transverse stiffness constant may be expressed as follows:

$$D_{Q_y} = S[E_c/(1 - \mu_c^2)] \tag{9}$$

Values of S, computed for variations in t_c, t_s, h, and θ. are presented in Figs. 5 and 6.

Experimental Results

Values of D_{Q_y} were determined experimentally from tests similar to those described in reference 1. Fig. 7 shows a simply supported beam with a concentrated load at the center. Local deflections at the support and loading points were made negligible by the employment of small pads. Corrections were made for the effect of these pads on maximum deflection. The beam was flexed three times, well within the elastic range, and a linear plot of load vs. maximum deflection was developed. This procedure was followed for two values of l: 10 in. and 7 in.

Considering both shear stiffness and bending stiffness of the beam, the deflection at the center was expressed as

$$\omega = (Pl^3/48D_y b) + (Pl/4D_{Q_y} b) \tag{10}$$

Using the test results, two simultaneous equations were solved to obtain D_{Q_y}

$$D_{Q_y} = \frac{l\eta}{4b} \frac{1 - \eta^2}{(\Delta\omega/\Delta p)_{7\text{ in.}} - (\Delta\omega/\Delta p)_{10\text{ in.}}\eta^3} \tag{11}$$

where $(\Delta\omega/\Delta p)_{7\text{ in.}}$ and $(\Delta\omega/\Delta p)_{10\text{ in.}}$ are the respective slopes of the load deflection curves, l = 10 in. and η = 0.7. Test results and comparable theoretical predictions are shown in Table 1.

References

[1] Libove, Charles, and Hubka, Ralph E., *Elastic Constants for Corrugated-Core Sandwich Plates*, NACA TN 2289, Feb., 1951.

[2*] Libove, Charles, and Batdorf, S. B., *A General Small Deflection Theory for Flat Sandwich Plates*, NACA Rep. 899, 1948.

[3*] Heilbron, C. H., and Foster, H., *Chordwise Shear Theory, Double-Skin Construction*, Rep. No. 2326, Lockheed Aircraft Corp., Sept. 4, 1941.

[4*] Reissner, Eric, *Finite Deflections of Sandwich Plates*, Journal of the Aeronautical Sciences, Vol. 15, No. 7, pp. 435–440, July, 1948.

* Background not referenced in the text.

For a thermopile generator in space, it is shown that there is an optimum cold junction temperature resulting in a minimum required area of radiating surface for given material properties and a given hot junction temperature.

The ratio of this optimum absolute cold junction temperature to the absolute hot junction temperature lies between 0.75 and 0.80 for a wide variety of conditions. Resulting values of the minimum required radiating surface area and overall thermal efficiency are presented for a broad range of material properties and hot junction temperatures.

Douglas L. Kerr
General Electric Company

Radiator Areas of Thermopile Generators in Space

THE DEMAND for ever-increasing quantities of electrical energy for use in space applications has long since led to investigations of methods other than batteries by means of which this energy can be supplied. Such methods include not only use of conventional rotating machinery, but also use of heretofore unconventional equipment such as thermopile generators, thermionic converters, and fuel cells.

A characteristic common to most of these systems is that they operate by receiving heat from an energy source, such as a nuclear reactor, a radioisotope, or radiation from the sun, and they convert only a part of this heat to electrical energy. The remainder, or waste heat, must then either be absorbed somewhere in the vehicle structure and cargo, or be rejected to space by means of thermal radiation. In most cases, the latter procedure is the only practicable method. Consideration of the size and weight of the resulting radiator structure then becomes one of the significant problems associated with the system design.

It is the purpose of this paper to discuss one aspect of this problem—namely, the required area of the radiating surface—with particular reference to thermopile generator applications. One thought behind this approach is that the radiating surface area provides a fairly good preliminary indication of size and weight, at least on a relative basis. Also, the results of such considerations provide an indication of some of the possibilities for design optimization of space power packages.

Radiating Surface Area Requirements, General Case

The net amount of heat that can be rejected per unit area from a radiating surface located in space can be written as:

$$q_R/A_2 = \epsilon\sigma T_R^4 - (q_s/A_2) \qquad (1)$$

where

q_R = net heat rejected from the surface, watt
A_2 = radiating surface area, cm.^{2}
ϵ = thermal emissivity of the radiating surface, dimensionless
σ = Stefan-Boltzmann constant, $\sigma = 5.73 \times 10^{-12}$ watt/cm.^{2} − °K.^{4}
T_R = temperature of the radiating surface, °K.
q_s = amount of absorbed radiation from external sources such as the sun, earth, etc. (hereafter referred to as absorbed solar radiation), watt

On the other hand, the amount of waste heat that must be rejected by a space power package of the type here considered is readily shown to be given by

$$q_2/P = (1 - \eta)/\eta \qquad (2)$$

where

q_2 = amount of waste heat that must be rejected, watt
P = net power output of the device, watt
η = overall thermal efficiency, defined by $\eta = P/q$, dimensionless
q = total heat input to the power package, watt

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Mr. Kerr graduated in 1946 from the University of Wisconsin with a B.S. degree in Mechanical Engineering. He joined the General Electric Company in the fall of that year and later completed the 3-year Advanced Engineering Program of that company. Since that time, he has been doing developmental engineering in the fields of fluid mechanics, thermodynamics, and systems associated with these fields. As a Mechanical Engineer in the Thermal Systems Section, Mechanical Engineering Laboratory, his recent work has been concerned with thermoelectric energy conversion.

If it is assumed that the net power output is dissipated and rejected elsewhere, q_2 becomes equal to q_R, and combination of Eqs. (1) and (2) yields the net power output per unit of radiating surface area as

$$P/A_2 = [\eta/(1 - \eta)][\epsilon\sigma T_R^4 - (q_s/A_2)] \qquad (3)$$

Some sample calculations based on Eq. (3) were made, both for the case where the absorbed solar radiation is assumed to be zero and for the case where the absorbed solar radiation is arbitrarily assumed to be 0.085 watt/cm.^{2}. This latter value is approximately half of the maximum incident radiant energy from the sun, earth, and space at an altitude of about 300 miles above the earth.[1] With this amount of absorbed radiation, the minimum possible radiating surface temperature for an emissivity of 0.9 is 359°K. (186°F.). The results are given in Fig. 1, which shows the power output per unit of required radiating surface area as a function of radiating surface temperature for various values of overall thermal efficiency.

Since the size of radiating surface has a large effect on overall weight, a quantity extremely important in space applications, it is desirable to have as high a value as possible of power output per unit radiating surface area. The desirability of having both a high efficiency and a high radiating surface temperature is thus apparent from Fig. 1. The strong effect of radiating surface temperature is particularly evident.

For the case where the absorbed solar radiation is assumed to be 0.085 watt/cm.^{2}, the pronounced effect of radiating surface temperatures less than 500–600° K. upon required radiating surface area is also apparent from Fig. 1. In an actual design, it should be possible to reduce the amount of absorbed radiation to a value less than this, but the need for high-temperature operation is believed to be sufficiently illustrated. Further, it is worth noting that, for purposes of control and relatively stable power output, it may be highly desirable to have radiating surface temperatures sufficiently hot that performance is but little affected regardless of whether the radiating surface is exposed directly to the sun or is in shadow.

Fig. 2 gives the same information as Fig. 1 for higher values of efficiency.

Specific Consideration of Thermopile Generators

It will be recalled that a thermopile generator consists basically of a number of thermocouples connected in electrical series. Each thermocouple is composed of two elements or legs—one containing what is usually

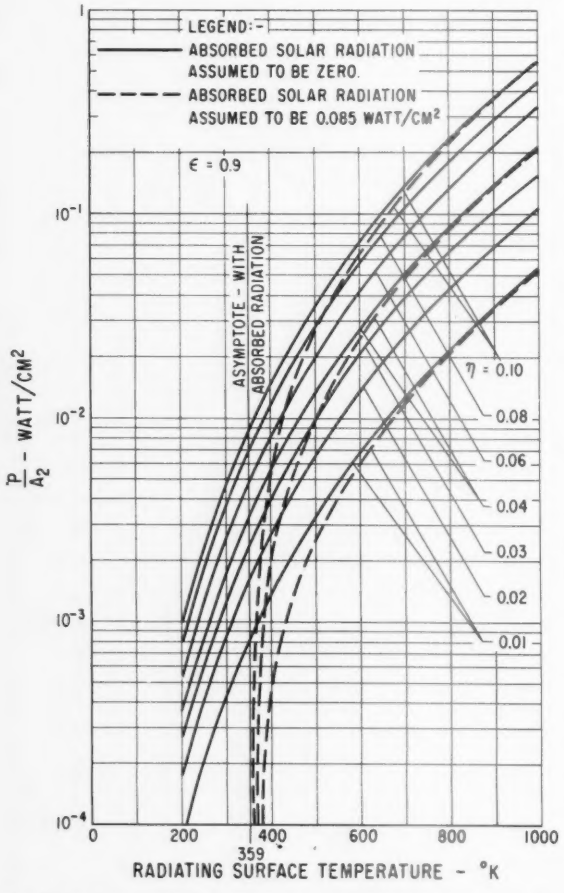

Fig. 1. Required radiating surface area to discharge waste heat of a power supply for space vehicles, low efficiency range.

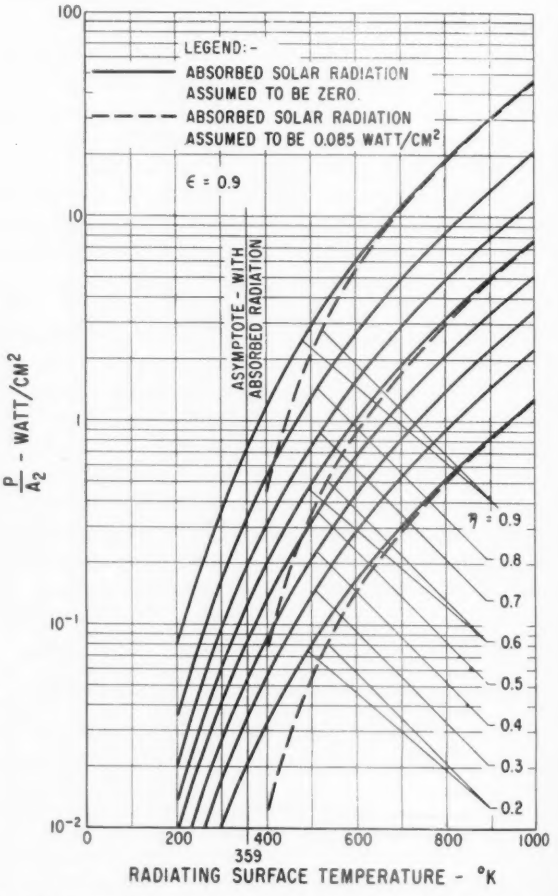

Fig. 2. Required radiating surface area to discharge waste heat of a power supply for space vehicles, high efficiency range.

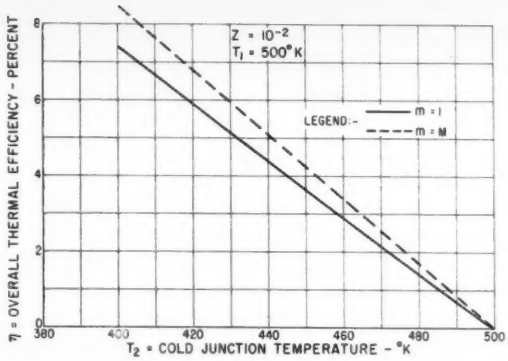

Fig. 3. Overall thermal efficiency of thermopile generator in space application. Absorbed solar radiation = 0.085 watt/cm.²; ϵ = 0.9.

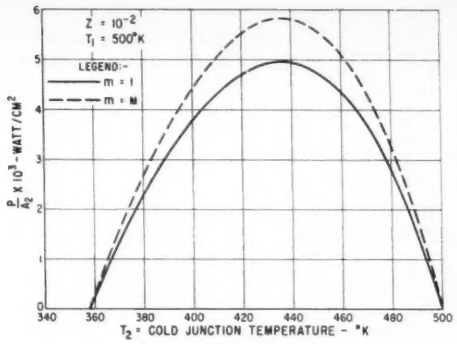

Fig. 4. Power output per unit area of radiating surface for thermopile generator in space application. Absorbed solar radiation = 0.085 watt/cm.²; ϵ = 0.9.

referred to as a positive thermoelectric material, while the other contains a negative thermoelectric material. In the generator, every other one of the junctions between these dissimilar materials is heated while the intermediate junction is cooled. The temperature difference between these hot and cold junctions gives rise to the Seebeck voltage which is the basis for the use of this sort of device as an electric generator.

For such a thermopile generator, the overall thermal efficiency to be used in Eq. (3) is a function of hot and cold junction temperatures, material properties, relative dimensions of the thermoelectric materials, and the ratio of the external electrical resistance (load resistance) to the electrical resistance of the thermoelectric material. This neglects the electrical energy dissipated in any conductors connecting adjacent thermocouple elements.

For best efficiency, the relative dimensions can be optimized. Assuming constant materials properties, the resulting overall thermal efficiency can be written as[2]

$$\eta = \frac{\dfrac{mZ}{(m+1)^2}(T_1 - T_2)}{1 + \dfrac{ZT_1}{m+1} - \dfrac{1}{2}\dfrac{Z(T_1 - T_2)}{(m+1)^2}} \qquad (4)$$

where

T_1 = hot junction temperature, °K.
T_2 = cold junction temperature, °K.
m = ratio of external electrical resistance to the resistance of the thermoelectric material; can be controlled by the designer
Z = Figure of Merit of the thermoelectric materials, a function of material properties; has the units 1/°K., and is discussed in more detail below

As can be seen from Eq. (4), the properties of the thermoelectric materials, in so far as they affect the thermal efficiency, can be grouped into the single parameter Z. This parameter, usually called the Figure of Merit, is given by

$$Z = \left\{(S_p - S_n)/[\sqrt{(\rho k)_p} + \sqrt{(\rho k)_n}]\right\}^2 \qquad (5)$$

where

S = Seebeck coefficient of the thermoelectric material (taking algebraic sign into account), volt/°K.
ρ = electrical resistivity of the thermoelectrical material, ohm-cm.
k = thermal conductivity of the thermoelectric material, watt/cm.-°K.
p, n = subscripts referring, respectively, to the positive and negative types of thermoelectric materials used to form each individual couple

For high efficiency, it is desirable to have large values of Figure of Merit. Heretofore, commonly used metallic thermocouple materials have Figures of Merit on the order of 10^{-4}. Using more recently developed materials, Figures of Merit on the order of 2×10^{-3} are now obtainable in the vicinity of room temperature, while values tend to decrease significantly as the operating temperature increases.

It should be pointed out that Eq. (4) assumes that all of the heat from the energy source passes through the thermoelectric elements. In some cases, deliberately or otherwise, the design geometry is such that this is not the case. In that event, Eq. (4) does not give the overall thermal efficiency of the power system, and its use in Eq. (3) is not valid.

It can be shown that the maximum power output per unit area or volume of thermoelectric material occurs when $m = 1$. This condition is thus of interest. On the other hand, it can also be shown that for maximum efficiency the value of m that should be used is given by[2]

$$m = M = \sqrt{1 + (Z/2)(T_1 + T_2)} \qquad (6)$$

Also, using this value of $m = M$, Eq. (4) reduces to the following form[2]:

$$\eta = \eta_M = \left(\frac{T_1 - T_2}{T_1}\right)\left[\frac{M-1}{M + (T_2/T_1)}\right] \qquad (7)$$

which is the maximum efficiency.

It is of interest, then, to investigate the effects of using $m = 1$ and also $m = M$ on efficiency as calculated from Eqs. (4) and (7), respectively, and in turn to use

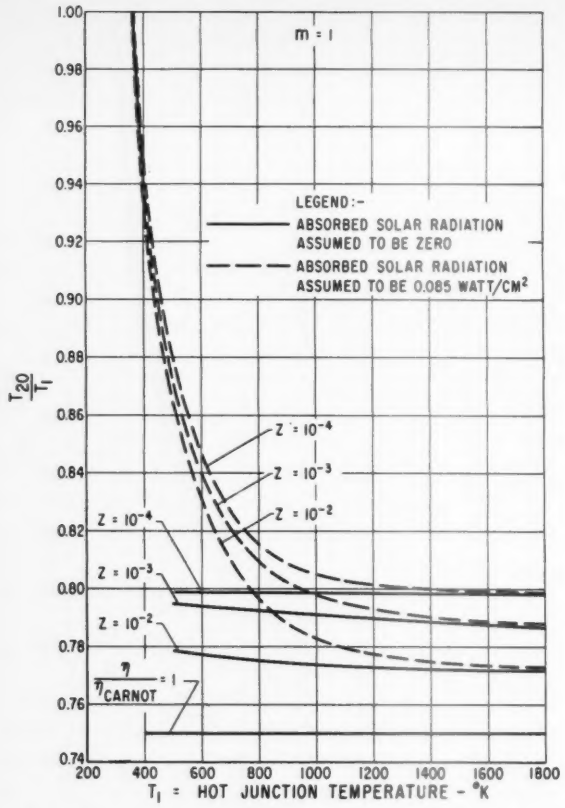
m = 1
LEGEND:-
ABSORBED SOLAR RADIATION ASSUMED TO BE ZERO
ABSORBED SOLAR RADIATION ASSUMED TO BE 0.085 WATT/CM²
Z = 10⁻⁴
Z = 10⁻³
Z = 10⁻²
η/η CARNOT = 1
T20/T1
T1 = HOT JUNCTION TEMPERATURE - °K

Fig. 5. Optimum cold junction temperature for minimum required radiating surface area for thermopile generator in space application; $\epsilon = 0.9$.

the resulting values of efficiency to determine P/A_2 from Eq. (3) for both $m = 1$ and $m = M$.

This has been done for two different values of Figure of Merit Z of 10^{-4} and 10^{-2}* and for two hot junction temperatures of 500° and 1,800°K. It was found that, for a Figure of Merit of 10^{-4}, the values of efficiency and power output per unit radiating surface area obtained using $m = 1$ were practically indistinguishable from the values obtained using $m = M$. On the other hand, the value of m has a measurable effect if the Figure of Merit is as high as 10^{-2}. This is illustrated by Figs. 3 and 4 which give, respectively, the overall thermal efficiency and the power output per unit radiating surface area as functions of cold junction temperature for a hot junction temperature of 500°K. The solid lines are for $m = 1$, and the dashed lines are for $m = M$. The temperature of the radiating surface is assumed to be equal to the cold junction temperature in Figs. 3 and 4.

It will also be noted from Fig. 4 that there is an optimum cold junction temperature for maximum power output per unit area of radiating surface for a given Figure of Merit and hot junction temperature. However, the value of this optimum cold junction temperature on Fig. 4 is, for all practical purposes, unaffected by the value of m. This same result was observed (when $q_s/A_2 = 0.085$ watt/cm.²) for the other combinations of Figure of Merit and hot junction temperature noted above. It is true even though the value of M, as will later be shown, can be significantly different from unity for these conditions.

An expression giving the value of this optimum cold junction temperature for minimum required radiating surface area is now of interest. By substituting Eq. (4) into Eq. (3) and differentiating with respect to cold junction temperature with all other variables held constant, this expression can be found. It can be written in the form

$$aT_{20}^2 + bT_{20} - c = 0 \tag{8}$$

where T_{20} is the optimum cold junction temperature for minimum required radiating surface area. It is assumed that T_{20} is equal to the radiating surface temperature. And

$$a = \frac{4Z}{(m+1)^2}\left(m + \frac{1}{2}\right) \tag{9}$$

$$b = \left[4 + \left(1 - \frac{q_s}{A_2}\frac{1}{\epsilon\sigma T_{20}^4}\right)\right]\left[1 + \frac{ZT_1}{m+1}\right] - \left[\frac{8Z}{(m+1)^2}\left(m + \frac{1}{2}\right)\right]T_1 \tag{10}$$

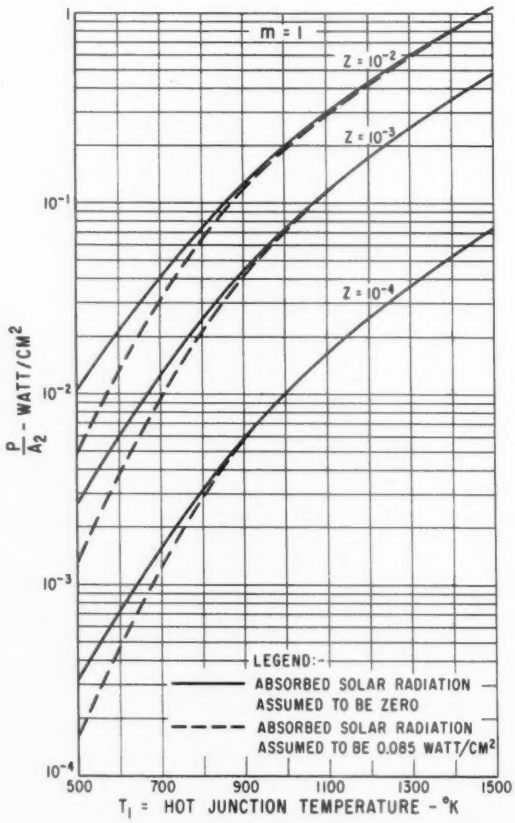
m = 1
Z = 10⁻²
Z = 10⁻³
Z = 10⁻⁴
P/A2 - WATT/CM²
LEGEND:-
ABSORBED SOLAR RADIATION ASSUMED TO BE ZERO
ABSORBED SOLAR RADIATION ASSUMED TO BE 0.085 WATT/CM²
T1 = HOT JUNCTION TEMPERATURE - °K

Fig. 6. Minimum required radiating surface area for thermopile generator in space application, low temperature range; $\epsilon = 0.9$.

* A value of Figure of Merit as high as 10^{-2} has not as yet been obtained at any temperature as far as the writer is aware. Calculations using this value have been carried out primarily for the purpose of illustrating the effects of taking an extreme case.

$$c = 4\left\{1 + \frac{Z}{m+1}\left[1 - \frac{m + (1/2)}{m+1}\right]T_1\right\}T_1 \qquad (11)$$

When q_s/A_2 is zero, this can be solved directly by the quadratic equation

$$T_{20} = (-b + \sqrt{b^2 + 4ac})/2a \qquad (12)$$

where the positive sign in front of the square root has been found to be the one giving the physically realizable solution.

When q_s/A_2 is not zero, Eq. (8) is not a true quadratic because of the dependence of b upon T_{20}. However, this dependence has been found to be of second order for the range of variables so far investigated. As a result, the solution can be obtained from Eq. (12) by a few iterations, where for the first trial q_s/A_2 is neglected in calculating b.

Results from Eq. (12) for $q_s/A_2 = 0$, $q_s/A_2 = 0.085$ watt/cm.^{2}, and $m = 1$ are shown on Fig. 5. Also shown on Fig. 5 is the limiting case of $T_{20}/T_1 = 0.75$ which is obtained when the value of efficiency used in Eq. (3) is assumed to be equal to that of a Carnot cycle —i.e.,

$$\eta = \eta_{Carnot} = (T_1 - T_2)/T_1 \qquad (13)$$

It is seen that, except at low hot junction temperatures with absorbed solar radiation, the value of T_{20}/T_1 varies little, essentially ranging between 0.75 and 0.8.

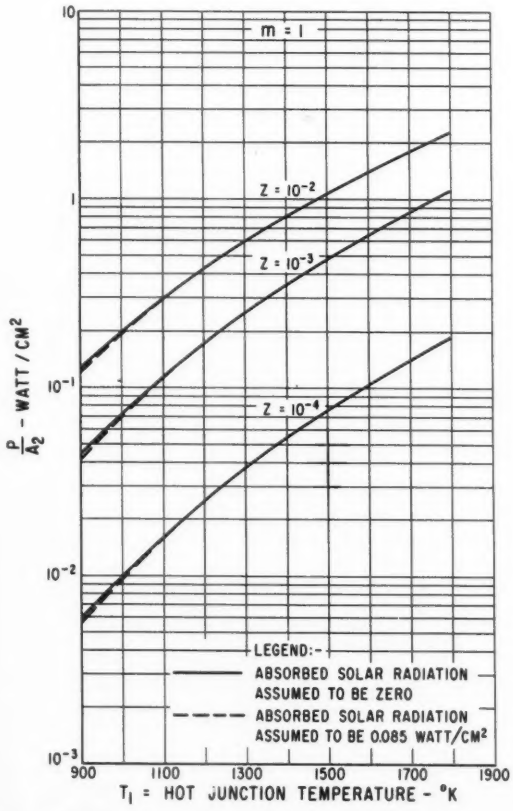
m = 1
Z = 10⁻²
Z = 10⁻³
Z = 10⁻⁴
LEGEND:-
ABSORBED SOLAR RADIATION ASSUMED TO BE ZERO
ABSORBED SOLAR RADIATION ASSUMED TO BE 0.085 WATT/CM²
P/A₂ - WATT / CM²
T₁ = HOT JUNCTION TEMPERATURE - °K

Fig. 7. Minimum required radiating surface area for thermopile generator in space application, high temperature range; $\epsilon = 0.9$.

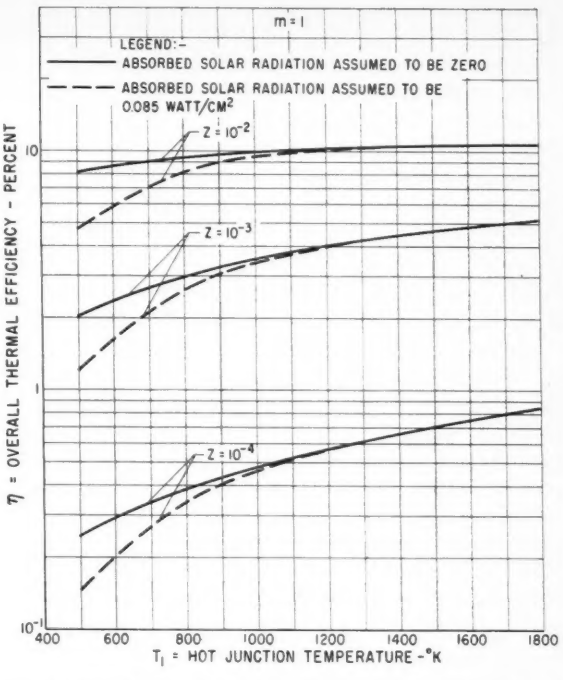
m = 1
LEGEND:-
ABSORBED SOLAR RADIATION ASSUMED TO BE ZERO
ABSORBED SOLAR RADIATION ASSUMED TO BE 0.085 WATT/CM²
Z = 10⁻²
Z = 10⁻³
Z = 10⁻⁴
η = OVERALL THERMAL EFFICIENCY - PERCENT
T₁ = HOT JUNCTION TEMPERATURE -°K

Fig. 8. Thermal efficiency of thermopile generator in space application for minimum required radiating surface area; $\epsilon = 0.9$.

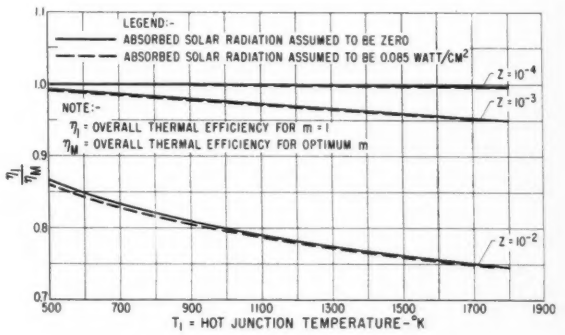
LEGEND:-
ABSORBED SOLAR RADIATION ASSUMED TO BE ZERO
ABSORBED SOLAR RADIATION ASSUMED TO BE 0.085 WATT/CM²
Z = 10⁻⁴
Z = 10⁻³
Z = 10⁻²
NOTE:-
η₁ = OVERALL THERMAL EFFICIENCY FOR m = 1
η_M = OVERALL THERMAL EFFICIENCY FOR OPTIMUM m
η₁/η_M
T₁ = HOT JUNCTION TEMPERATURE -°K

Fig. 9. Ratio of efficiency at $m = 1$ to maximum efficiency under conditions otherwise giving minimum area of radiating surface for $m = 1$. Space application of thermopile generator: $\epsilon = 0.9$.

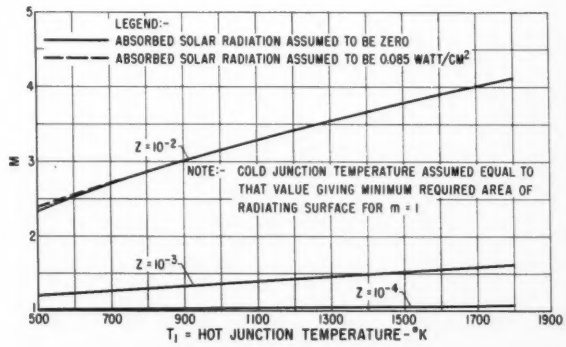
LEGEND:-
ABSORBED SOLAR RADIATION ASSUMED TO BE ZERO
ABSORBED SOLAR RADIATION ASSUMED TO BE 0.085 WATT/CM²
Z = 10⁻²
Z = 10⁻³
Z = 10⁻⁴
NOTE:- COLD JUNCTION TEMPERATURE ASSUMED EQUAL TO THAT VALUE GIVING MINIMUM REQUIRED AREA OF RADIATING SURFACE FOR m = 1
M
T₁ = HOT JUNCTION TEMPERATURE -°K

Fig. 10. Optimum resistance ratio for maximum efficiency under conditions otherwise giving minimum required area of radiating surface for $m = 1$. Space application of thermopile generator: $\epsilon = 0.9$.

Using the optimum values of $T_2/T_1 = T_{20}/T_1$ given on Fig. 5, the maximum values of P/A_2, which correspond to minimum values of radiator area, have been calculated from Eqs. (4) and (3) for $m = 1$ and various values of Figure of Merit and hot junction temperature. Results are shown on Figs. 6 and 7 for low and high values, respectively, of hot junction temperature. The corresponding overall thermal efficiencies are shown in Fig. 8. Fig. 9 gives the ratio of this thermal efficiency obtained at $m = 1$ to the thermal efficiency obtained from Eq. (7) at the same temperatures using $m = M$ as given by Eq. (6). The values of M which result are also shown on Fig. 10.

The maximum possible values of P/A_2 for a thermopile generator would be given by optimization of Eq. (3) using the value of $\eta = \eta_M$ as given by Eq. (7). Because of the temperature dependence of M, this procedure does not look very promising analytically. However, a good approximation to these maximum possible values has been obtained by the following procedure.

It was previously noted that, for $q_s/A_2 = 0.085$ watt/cm.^{2}, there is a negligible difference between the optimum cold junction temperature obtained using $m = 1$ and that obtained using $m = M$ for the range of values of Figure of Merit and hot junction temperature considered here. It is reasonable to assume that this same insensitivity to the value of m also holds true when $q_s/A_2 = 0$. Making this assumption, the optimum cold junction temperatures given on Fig. 5 for either value of q_s/A_2 are essentially valid both for $m = 1$ and for $m = M$. Using these temperatures and the values of $\eta = \eta_M$ given by Eq. (7), the resulting values of power output per unit radiating surface area have been calculated from Eq. (3) and are plotted on Figs. 11 and 12. These represent the maximum possible values that can be expected from a thermopile generator.

Discussion

Assuming adequate reliability, the single most important parameter of a power package for space applications is probably the weight of the system. Obviously, the radiator is only one of the components making up the total weight, which must also include the generator itself, the heat source, and whatever controls may be necessary. Thus the design conditions producing minimum radiating surface area will not necessarily result in the minimum weight of the complete system.

Nevertheless, the weight of the radiator will generally be a very important part of the system weight. Hence it is felt that considerations of the type presented here are useful from the standpoint of indicating the nature of the variation of radiator size with materials properties and operating temperatures, as well

(*Continued on page 66*)

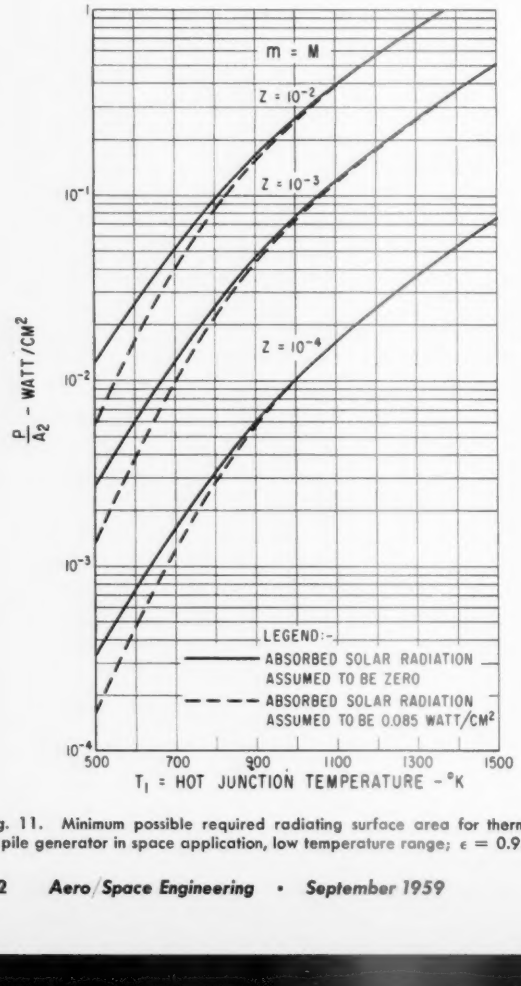
m = M
Z = 10⁻²
Z = 10⁻³
Z = 10⁻⁴
P/A₂ - WATT/CM²
LEGEND:-
ABSORBED SOLAR RADIATION ASSUMED TO BE ZERO
ABSORBED SOLAR RADIATION ASSUMED TO BE 0.085 WATT/CM²
T₁ = HOT JUNCTION TEMPERATURE - °K

Fig. 11. Minimum possible required radiating surface area for thermopile generator in space application, low temperature range; $\epsilon = 0.9$.

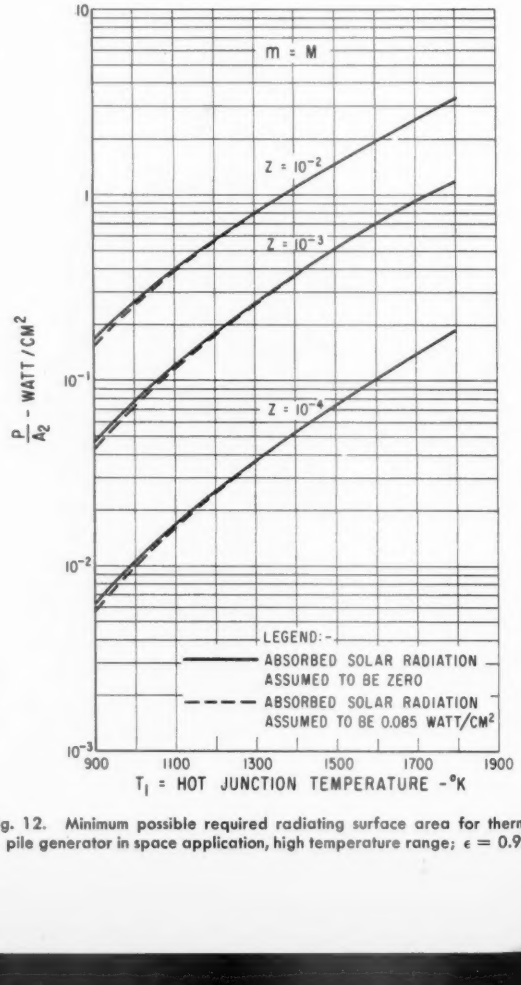
m = M
Z = 10⁻²
Z = 10⁻³
Z = 10⁻⁴
P/A₂ - WATT/CM²
LEGEND:-
ABSORBED SOLAR RADIATION ASSUMED TO BE ZERO
ABSORBED SOLAR RADIATION ASSUMED TO BE 0.085 WATT/CM²
T₁ = HOT JUNCTION TEMPERATURE - °K

Fig. 12. Minimum possible required radiating surface area for thermopile generator in space application, high temperature range; $\epsilon = 0.9$.

This is the conclusion of a two-part paper. The first part, dealing with the characteristics of the flight regime under investigation, was published in the August issue.

A Quantitative Analysis of the Characteristics and Limitations of

Aerodynamic Flight Within the Atmosphere

Part II—Limitations

William Chester Walter, AFIAS
Avro Aircraft Limited, Canada

The Cruising Flight Regime

Generally speaking, the larger the value of (L/D) the greater is the range. In order to fly at a given Mach Number at or near $(L/D)_{A\max}$, the aircraft must, of course, maintain a corresponding angle of attack. For a given configuration, the values of $(L/D)_{A\max}$ and the corresponding $C_{L\text{opt}}$ values vary with Mach Number only.

It is characteristic of high-speed aerodynamics that the magnitude of the C_L attainable reduces as Mach Number increases and the range of C_L values also becomes severely restricted. This condition is the result of several factors. For example, at a given speed and altitude the severity of aerodynamic heating increases with increasing angle of attack. Also, for a given configuration, as the Mach Number increases the lift coefficient associated with $(L/D)_{A\max}$ decreases. In addition, the severity of the demands made on aircraft aerodynamic pitch controls is increased in high-speed flight making it, increasingly more difficult to maintain appreciable angles of attack as the Mach Number increases. In view of this restriction in attainable C_L it appears that flight at appreciable values of (L/D), and thus long range, can only be accomplished using cruise vehicles which have a configuration which exhibits large values of $(L/D)_{A\max}$ at low angles of attack.

Fig. 8 is a plot of $C_{L\text{opt}}$ vs. Mach Number for the typical configuration used in Fig. 5, assuming turbulent flow conditions. The reduction in $C_{L\text{opt}}$ with increasing Mach Number is apparent. Values of $C_{L\text{opt}}$ for many typical aircraft systems are contained within the crosshatched area. These values, representing a large variety of configurations, are seen to approach the same magnitude as those shown for the typical configuration of Fig. 5 as Mach Number increases, the larger values being associated with canard configurations. Thus, it appears that above a speed of about Mach 4 the values of $C_{L\text{opt}}$ vs. Mach Number for vehicles designed for aerodynamically efficient flight at hypersonic speed may lie within a narrow band, as shown by the dashed lines on Fig. 8.

Fig. 9 is a plot of wing loading vs. Mach Number with altitude as a parameter. This curve is a plot of Eq. (5) using the C_L values of Fig. 8 which illustrates that centrifugal lift has the property in this expression of bowing out the constant altitude lines at low values of wing loading and high Mach Number, and causing the constant altitude lines about 100,000 ft. to converge very quickly and become asymptotic at approximately Mach 24 or satellite speeds. Because of the C_L values used in Eq. (5), one conclusion which may be drawn from Fig. 9 is that above 100,000 ft. and M-4 each value of wing loading on a constant altitude line closely approximates the maximum allowable wing loading of an aircraft for efficient unaccelerated level flight at that altitude and corresponding speed. This limitation is not considered valid below Mach 4 since the restrictions on $C_{L\text{opt}}$ are less severe, as shown in Fig. 8.

Of greater importance, however, is the conclusion that Fig. 9 is reasonably valid for any aircraft configuration in flight at max L/D at supersonic and hypersonic speeds due to the narrow limits of $C_{L\text{opt}}$ previously discussed.

Within the current state of the art, 20 lbs./ft.^{2} is considered the minimum empty wing loading structurally attainable for aircraft designed to fly at supersonic speeds. Fig. 10 is a plot of altitude vs. Mach Number showing the 20 lb./ft.^{2} wing loading curve based on Fig. 9. This curve, of course, represents the conditions at the end of cruise (point f on Fig. 1). In order

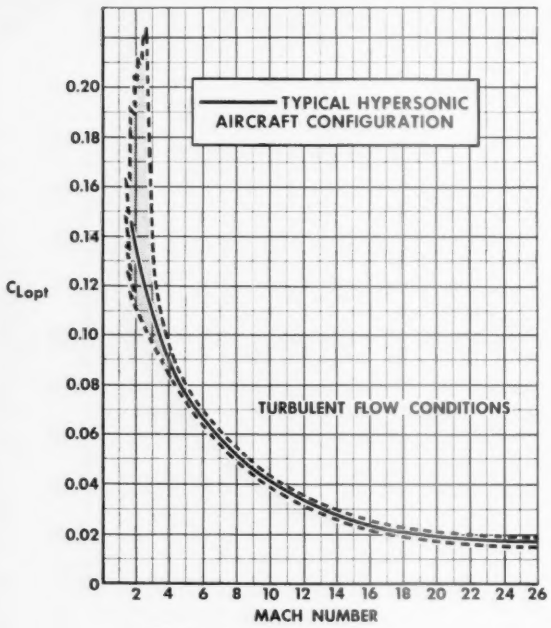

Fig. 8. C_{Lopt} vs. Mach Number.

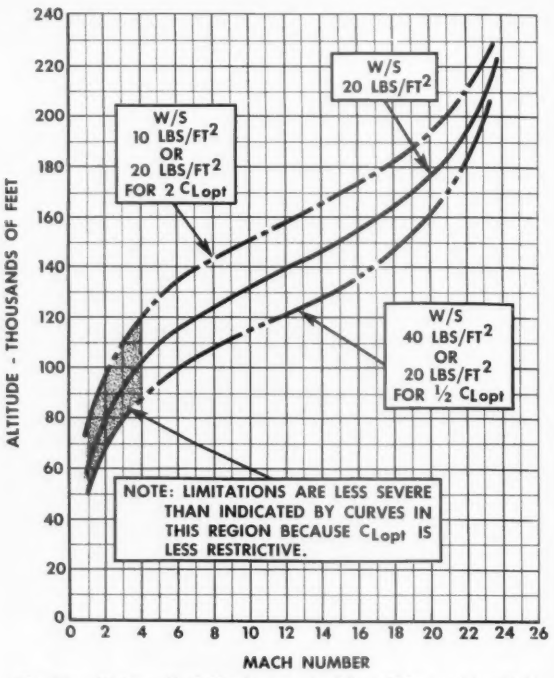

Fig. 10. Minimum Mach Number required for efficient cruising flight.

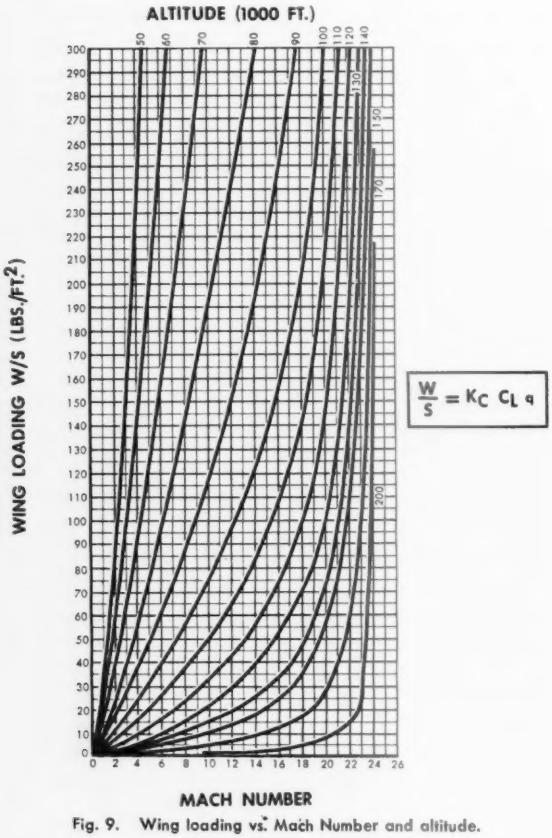

Fig. 9. Wing loading vs. Mach Number and altitude.

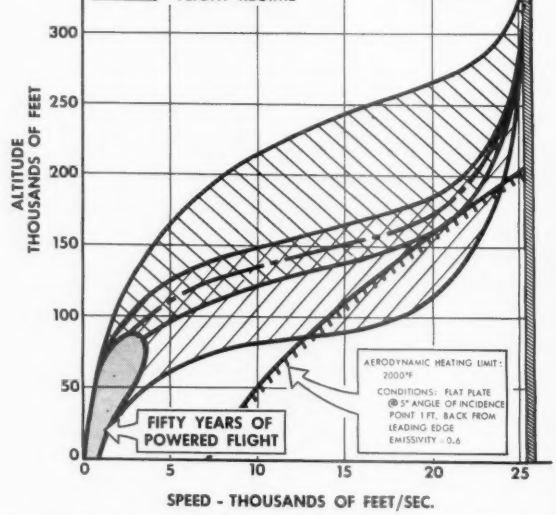

Fig. 11. The practical limits of aerodynamic flight within the atmosphere.

to initiate a cruise flight at a given altitude, the initial conditions must be beneath this curve. For example, the curve crosses 120,000 ft. at Mach 7, therefore, to initiate a cruise at 120,000 ft., flight at a higher Mach Number than 7 is necessary.

Notice that above 100,000 ft. the slope of the curve decreases markedly such that the speed necessary for efficient sustained flight at altitudes approaching 200,000 ft. is rapidly nearing satellite speed. For a given Mach Number cruising flight above the solid line is considered increasingly impractical and difficult, and accompanied by an increasingly severe penalty in range as the altitude increases. The region below the solid line is considered to be in the cruising flight regime.

Some measure of the accuracy of this estimate may be obtained, as follows. Doubling the $C_{L_{opt}}$ values assumed or halving the minimum wing loading of 20 lbs./ft.^{2} assumed results in the dashed curve shown on Fig. 10. On the other hand, halving the $C_{L_{opt}}$ values assumed or doubling the 20 lb./ft.^{2} wing loading assumed results in the double dashed curve on Fig. 10. Neither of these extremes is considered realistic for flight near L/D max. Also, as the flight speed increases, the 20 lbs./ft.^{2} estimate becomes optimistic due to the additional structural weight required in the basic aircraft to provide adequate aerodynamic heating protection.

Turbulent flow conditions were assumed throughout this analysis. If, in fact, laminar flow conditions were realized in flight, the $(L/D)_{A_{max}}$ values would increase and be reasonably constant for the whole Mach Number range; however, the angle of attack for $(L/D)_{A_{max}}$ would be shifted toward zero. The resulting reduction of the $C_{L_{opt}}$ values will be small and have little effect on the limits defined by the curves in Fig. 10.

Although a unique approach to the problems of high altitude sustained flight could result in a point design between the solid and dashed curve, the solid curve is considered representative of the practical upper limit of cruising flight within the earth's atmosphere with today's know-how.

The Practical Limits of Aerodynamic Flight

Fig. 11 is a plot of altitude in thousands of ft. vs. speed in thousands of ft. per sec. showing both the cruising vehicle flight regime and the aerospace vehicle flight regime. The upper limit of the aerospace vehicle flight regime is defined on the diagram as a constant wingloading line of 20 lbs. per ft.^{2} for a lift coefficient of one (high angle of attack flight). This condition was selected as the practical limit attainable within the current state of the art and the foreseeable future. The lower limit of the aerospace vehicle flight regime was selected as a constant wing loading line of 40 lbs. per ft.^{2} for the lift coefficient distribution shown in Fig. 8; 40 lbs. per ft.^{2} was chosen because of the limits of aerodynamic heating tolerance capabilities which will exist in the foreseeable future (note temperature limit line). The upper limit of the cruising vehicle flight regime was optimistically chosen as a constant wingloading line of 10 lbs. per ft.^{2} for the lift coefficient distribution of Fig. 8 to account for possible future improvements in fabrication of very light airframe structures. The bottom limit is defined as a constant wing loading line of 200 lbs. per ft.^{2} which is about the highest wingloading still within the realm of reasonable practicability. Notice that these two flight regimes overlap by a magnitude of only 30 lbs. per ft.^{2} in wingloading.

The constant speed cruise portion of a cruising vehicle flight would appear in Fig. 11 as a vertical line within the cruising vehicle flight regime connecting the initial cruising altitude with the final cruising altitude attained as a result of the reduction of vehicle weight as fuel is consumed. The gliding flight path of an aerospace vehicle, on the other hand, would trace out a constant wingloading line through the aerospace flight regime of Fig. 11 since its weight remains essentially unchanged in the glide phase.

Again, within the current state of the art it appears that a skin temperature of about 2,000°F. is representative of the limit of engineering capability in handling aerodynamic heating with available materials. At this temperature limit, as shown in Fig. 11, access to a large portion of the cruising vehicle flight regime, as defined aerodynamically, is cut off between speeds of 12,000 and 22,000 ft. per sec. leaving only a very narrow practical cruising flight region accessible in the vicinity of 20,000 ft. per sec. This temperature limit line as shown is applicable only to vehicles flying at low angles of attack. This limit line shifts upwards as the angle of attack flown is increased which would be the case for vehicles operating in the region between the upper limit of the cruising flight regime and the upper limit of the aerospace vehicle flight regime. Therefore, a vehicle operating along the upper limits of the aerospace regime would experience about the same magnitude of skin temperature as its lower flying counterpart at the same speed.

Flight along the upper limit, however, would be characterized by a reduction in the overall magnitude of aerodynamic heating relative to flight along the lower limit due to the fact that the kinetic and potential energy is dissipated at a much higher rate along the upper path. In fact, the total flight time along the upper path would occur in about one quarter the time to fly along the lower aerospace flight regime over an equal interval of speed.

As a matter of interest, the capability resulting from the past 50 years of powered flight is shown in Fig. 11. It should be remembered that this figure represents essentially aerodynamic and structural limits. The problem of providing suitable propulsion systems for operation beyond today's capabilities may well deny man the use of some portions of the cruising flight regime as defined for practical reasons. This should not be the case for the aerospace regime which

may well be expanded by improvements in the state of the art in the future, which thus far cannot be predicted.

Conclusions

The analysis of the characteristics of the aerodynamic flight regime showed that centrifugal lift has a profound influence on the limitations of both cruising and aerospace vehicle flight, and that the effects of the variation of the earth's gravitational acceleration are negligible in this area. Having defined an expression for centrifugal L/D, it becomes possible to determine much information concerning the performance of a given configuration in the supersonic and hypersonic flight regimes using model test data. The above statement hold equally true for aerospace vehicles.

It is evident from Fig. 10 that in order to fly a winged vehicle in efficient cruising flight close to the upper limits of the cruising vehicle flight regime, the vehicle must be designed for low wing loading. Flight at low angles of attack is indicated due to the limitations on optimum lift coefficient. The cruising flight regime representing current state of the art may be defined as the area below the solid curve on Fig. 10; however, the curve is not considered strictly valid below Mach 4 because the restrictions as $C_{L_{opt}}$ are not as severe at the low supersonic speeds. The curve shows that above 100,000 ft. a small increase in altitude is accompanied by a large increase in speed required for cruising flight at that altitude. For higher wing loadings the trend is identical; however, the reduction in the slope of the curve occurs at a lower altitude. Fig. 11 shows the upper limit of the cruising flight regime as a 10 lbs. per ft.^{2} line taking into account possible future state of the art advances in low weight aircraft structures but should be accepted cautiously.

Fig. 11 is felt to be representative of a quantitative measure of the practical aerodynamic and structural heating limits of aerodynamic flight within the atmosphere.

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Aircraft Localizer Guidance Systems (Continued from page 45)

$$d \cong \theta_t S \qquad \text{(A-8)}$$

where d is width of beam in feet at distance S from transmitter, and θ_t is beam width in radians; also

$$\rho_f = M/d \qquad \text{(A-9)}$$

where M is stop-to-stop reading in microamperes on localizer deviation indicator.

Therefore, by combining Eqs. (A-8) and (A-9), we have

$$\theta_t = M/\rho_f S \qquad \text{(A-10)}$$

References

[1] *Automatic Flight*, prepared by RTCA SC-18, Paper No. 151-56/DO-74, Radio Technical Commission for Aeronautics, Washington, D.C.

[2] *Notes on ILS Localizer Standardization*, Report No. 5245–4027, Sperry Gyroscope Company, Great Neck, N.Y.

[3] Eshbach, Ovid W. (Ed.), *Handbook of Engineering Fundamentals*; John Wiley & Sons, Inc., New York, 1952.

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Thermopile Generators in Space (Continued from page 62)

as providing some insight into the optimization problems involved in space power package systems. Furthermore, the values of power output per unit radiating surface area shown in Figs. 11 and 12 give, to close approximation, the maximum possible values obtainable from a thermopile generator and thus can be useful in preliminary size investigations.

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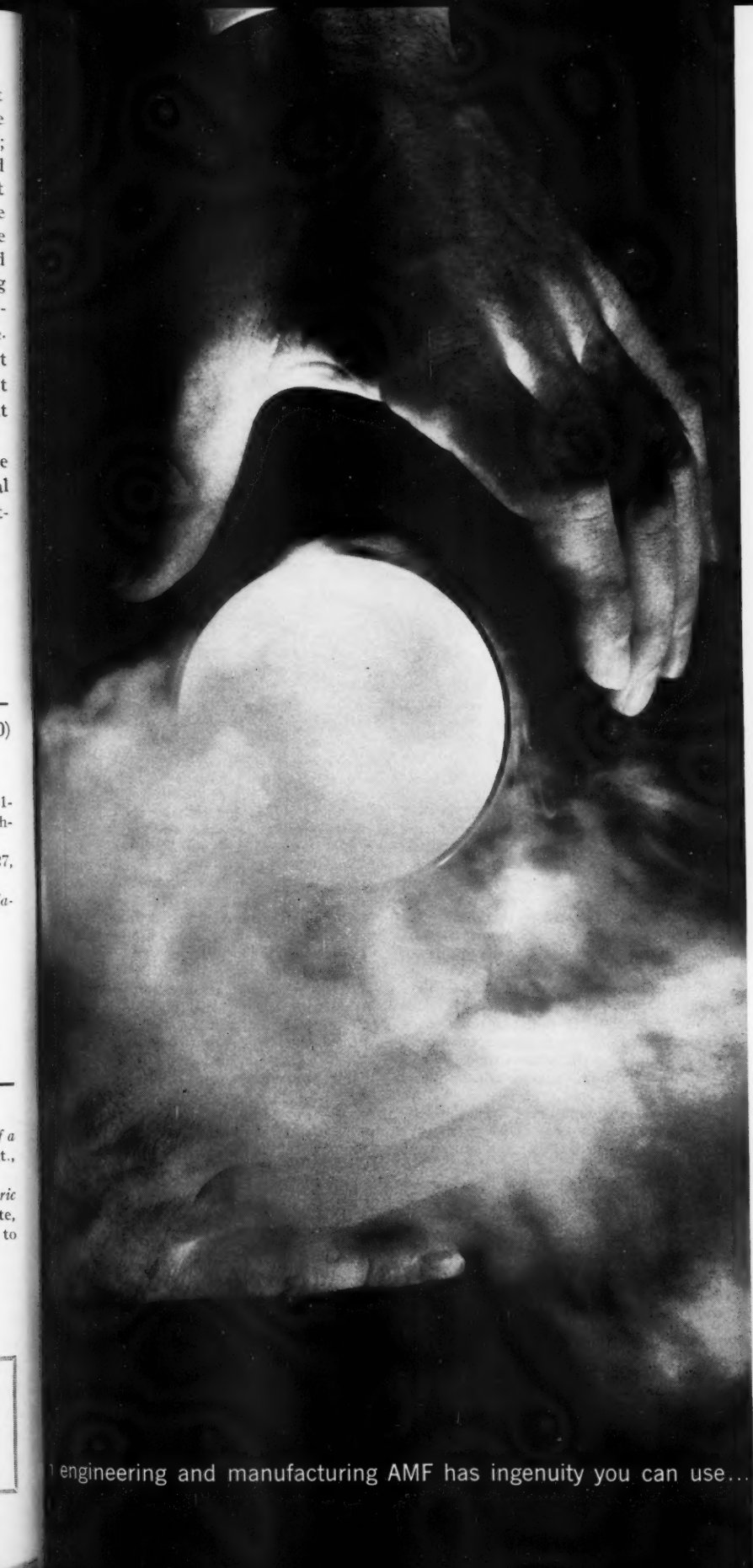

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Ex-IAS President Looks at an Engineer's Future

By a series of undemonstrated errors our technology can become our master—it can become and remain our servant only if we strive to avoid error, or, having failed to avoid it, we have the courageous intelligence to continue to search for truth. This was one of the thoughts expressed by **Edward C. Wells,** Vice-President and General Manager of Boeing Airplane Co., in his talk at the June 26 meeting on **"An Engineer Looks at the Future."**

One way of estimating the future, he said, is to take a look at the past and then extrapolate into the future. He noted that December, 1958, was the 55th anniversary of the Wright Brothers' first flight, and that the problems that had to be solved by them to insure success were still very much with us, appearing to be critical also for many future developments. These include propulsion, materials, guidance and control, stability, weight and drag—and, certainly, the element of cost. During these 55 years, we have gone through cycles of research and exploration, followed by exploitation. Today, he said, we are beginning to explore the potential of supersonic, hypersonic, orbital, and space flight, but, as we enter the Space Age, he noted that there was one important difference from the past—it is by no means clear yet whether there is an appropriate reward of tangible nature awaiting those who make a massive hardware assault on space.

After reviewing the developments that have occurred during the last 55 years, Mr. Wells observed that two recent ones offer a promise to the passenger who wants to go a long way in a short time. These are the turbo-fan engine, which offers, theoretically at least, a promise of efficient application to almost any high subsonic airplant, and the supersonic transport. The question of whether the supersonic transport will be developed and can be commercially successful will be answered in the affirmative if it offers advantages to the passenger consistent with the cost. Mr. Wells said that he assumed in the next generation of transport aircraft there exists a potential for operation at 2.5 Mach Number while flying within the atmosphere. He said, however, that no arbitrary limit should be placed on our study of the problem and that we must continue to determine practical and economic limits of our conquest of the outer atmosphere and the fringes of space.

Taking a look at the prospects for the air commuter, he conjectured on whether vertical take-off and landing devices other than the helicopter would come into general use. He said that this was a field of development in which only the surface had been scratched; helicopter capability without helicopter shortcomings is still a dream, but the potential utility involved might very well bring it to some form of reality.

Turning to military trends of the future, Mr. Wells said that it was characteristic of development cycles for the military programs to lead the commercial in the exploitation of new scientific and engineering knowledge, often with a correspondingly higher risk factor. A critical appraisal, however, could result in safer military systems with little real loss in military effectiveness.

Mr. Wells said the limiting military factors that are foreseeable in the future are money, materials, and manpower—manpower with respect to quantity and especially quality—the ultimate limit being the limit of human intelligence. A space environment, he said, might expose us to limits of human endurance, and certainly it would require a higher order of intelligence than we have consistently exercised if we are to have a reasonable sensible program of exploration and exploitation.

Thus, in the combination of space technology and weapons of mass destruction, Mr. Wells said that we have possibilities before us which will require the application of superhuman intelligence. Two important factors on which intelligent programs must be ultimately based, he said, are exploratory research for our long-term military and commercial future, and the ability to apply more fundamental knowledge more logically.

Mr. Wells referred to Dr. Edward Teller's belief that historically every 100 years have brought about a doubling of the store of human knowledge. If this is so, and there's no reason to believe otherwise, he said, we are faced with a formidable problem. The products on which we work are becoming more and more comprehensive in nature, while at the same time our store of available knowledge is increasing rapidly. This means that we must either develop superscientists and engineers capable of producing and absorbing knowledge at an ever-increasing pace, or that we must learn to train each individual well in an area suited to his capability while at the same time perfecting our ability to operate in such a way as to be effective on any major program.

If the engineer can recognize the importance of improving his store of new knowledge and develop governmental, educational, and management leadership to preserve and make use of such knowledge, and, having these two assests, if he can use them intelligently to design end products which are useful, simple, economical, safe, durable, and reliable, then certainly engineers have a challenging future to look forward to.

The care and feeding of a missile system

It takes more than pressing a button to send a giant rocket on its way. Actually, almost as many man-hours go into the design and construction of the support equipment as into the missile itself. A leading factor in the reliability of Douglas missile systems is the company's practice of including all the necessary ground handling units, plus detailed procedures for system utilization and crew training. This complete job allows Douglas missiles like THOR, Nike HERCULES, Nike AJAX and others to move quickly from test to operational status and perform with outstanding dependability. Douglas is seeking qualified engineers and scientists for the design of missiles, space systems and their supporting equipment. Some immediate openings are described on the facing page. Please read it carefully.

Alfred J. Carah, Chief Design Engineer, discusses the ground installation requirements for a series of THOR-boosted space probes with Donald W. Douglas, Jr., President of DOUGLAS

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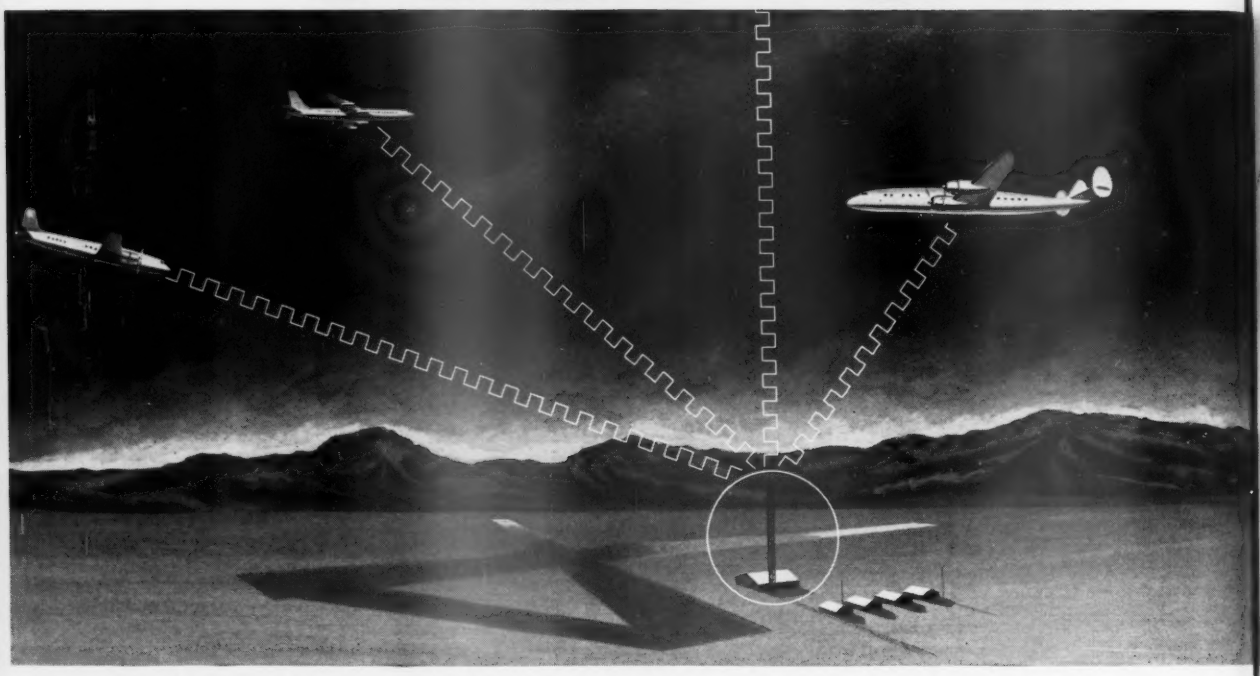

AGACS, Experimental Automatic Ground/Air/Ground Communication System is a new concept in Air Traffic Control Communications to meet the accelerated pace of increased air traffic. Primary objectives are efficient usage of frequency spectrum, added safety through increased reliability and reduced burden to pilot and controller, and adaptability to all classes of aircraft. AGACS provides compatibility with existing ground and airborne communication equipment, selective addressing of information, and a minimum number of frequency changes during flight. The system utilizes two-way time division data transfer over existing ground and air communication links to provide an automatic, mutual exchange of information. The airborne facilities display to the pilot the last significant Air/Ground and Ground/Air message quantities, while the controller may recall from central memory-storage equipment the last Air/Ground and Ground/Air message quantities for display. The AGACS program is still in the developmental stage. In August, 1959, RCA provided initial models of both airborne and ground equipments for the Bureau of Research and Development of the Federal Aviation Agency for extensive experimentation and flight tests.

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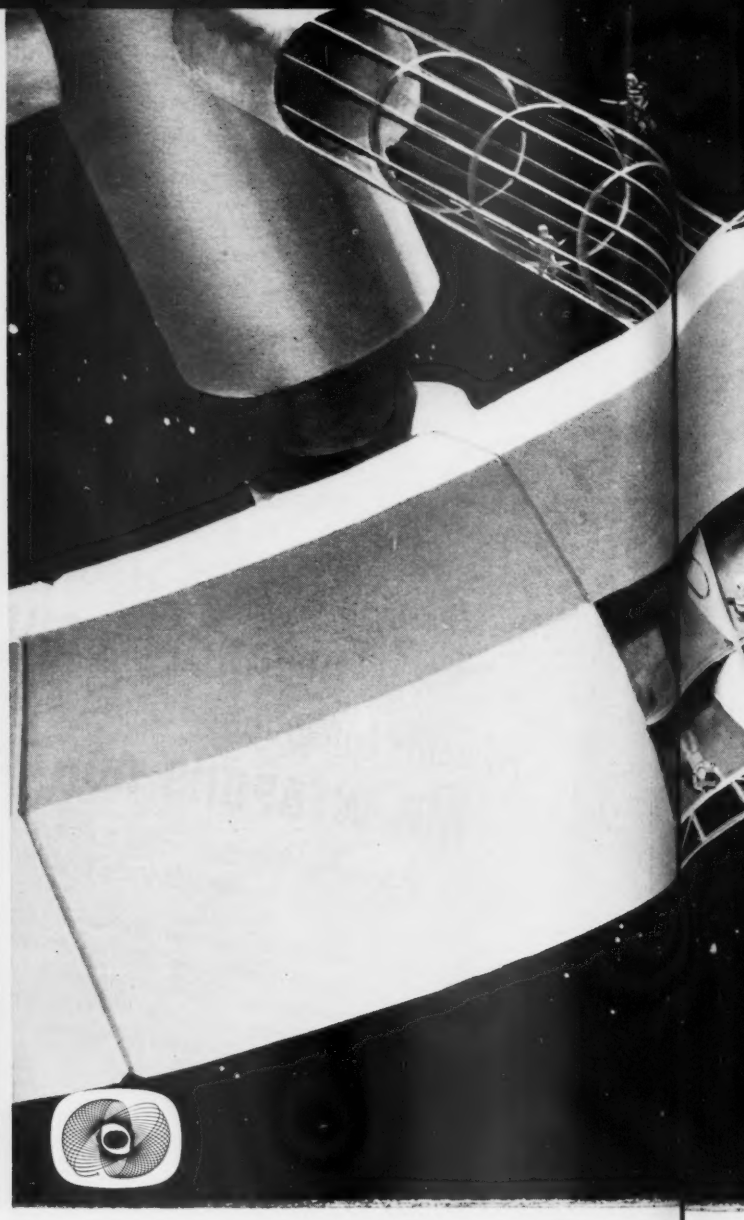

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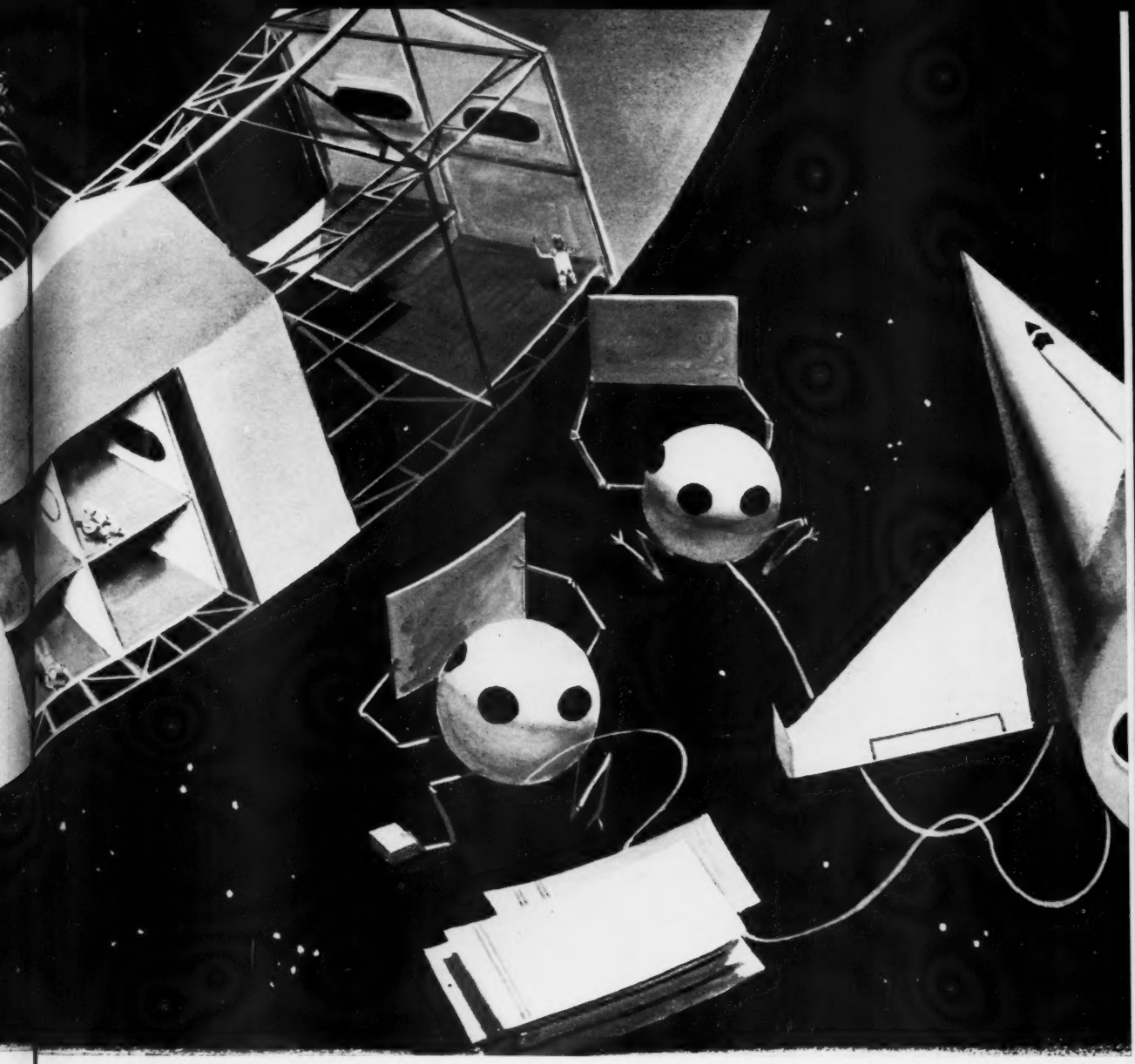

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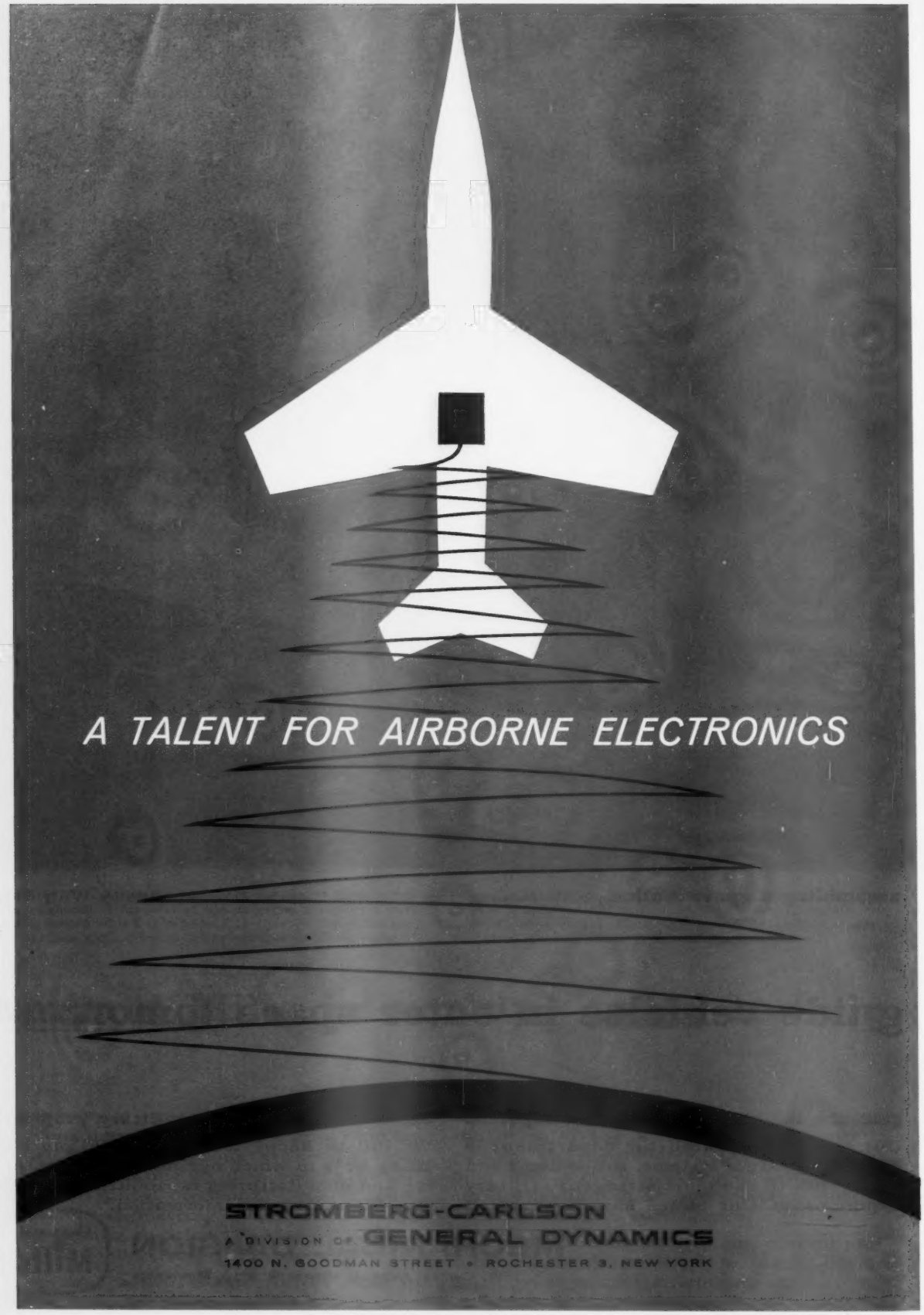
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CP 428 (Sept., 1957) 1959. 26 pp. BIS, New York, $0.72.

An Investigation of a Low-Drag Auxiliary Body Utilizing Favorable Interference. Anthony Martellucci. (*Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 432*, Dec., 1957.) *J. Aero/Space Sci.*, Aug., 1959, pp. 538–540.

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The Response of an Airplane to Random Atmospheric Disturbances. F. W. Diederich. *U.S., NACA Rep. 1345*, 1958. 36 pp. 18 refs. Supt. of Doc., Wash., $0.35. Extension of the statistical approach to the gust-load problem by considering the effect of lateral variation of the instantaneous gust intensity on the aerodynamic forces.

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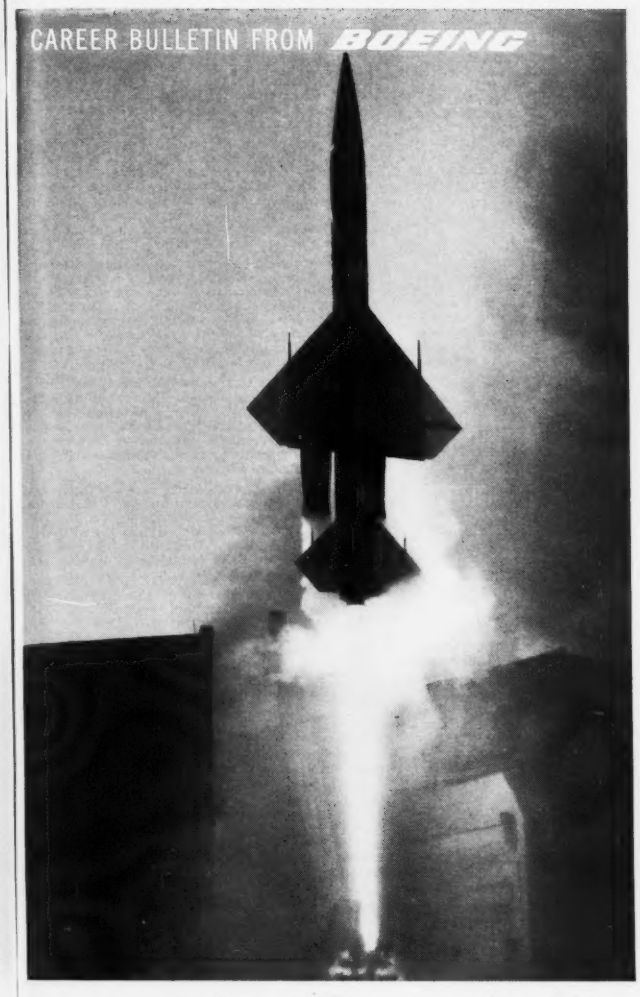

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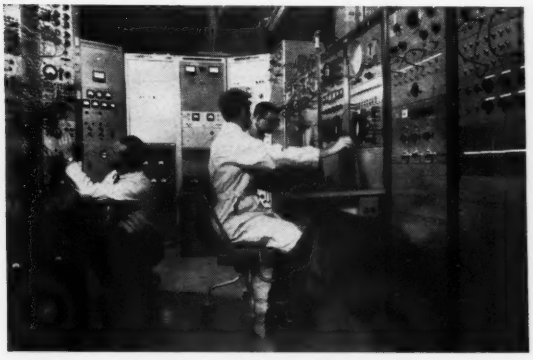

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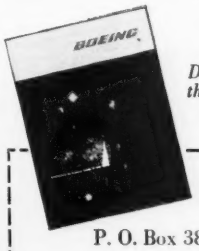

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DC-3 Economics vs. Jet Age Realities. P. W. Cherington. *Air Line Pilot*, May, 1959, pp. 4–7. Discussion of four basic airline problems: (1) marketing, (2) scope of the service, (3) economics of size, and (4) financial and human resources.

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Control Systems, Automatic Pilots

Sampled-Data Techniques Applied to a Digital Controller for an Altitude Autopilot. Appendix A—**Simulation of the Sampled-Data System.** Appendix B—**An Electronic Sample-Hold Circuit.** S. F. Schmidt and E. V. Harper. *U.S., NASA Memo. 4-14-59A*, June, 1959. 71 pp. Study showing that (a) considerations of the sensitivity of the response to parameter variations and abruptness of response to transient inputs preclude the use of finite settling time design, and (b) continuous sytem design concepts can be used to select the dominant poles of the closed-loop pulse transfer function so as to achieve a desired transient response. Results of a study of the design for a fourth-order plant are presented for the case where the plant is taken as an aircraft and the system as the control of the aircraft altitude.

Vliianie Nekotorykh Tipichnykh Nelineinostei na Nastroiku Avtopilota. M. E. Salukvadze. *Avtom. i Telemekh.*, May, 1959, pp. 553–563. In Russian. Study of the effect of certain typical nonlinearities on the automatic pilot adjustment. Such aspects as the limitation of the aileron deflection angle, the longitudinal stability of the aircraft, and the general conditions for stability limits are covered.

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Communications of the Future. Frank Leary. *Electronics*, July 3, 1959, pp. 37–41. Discussion covering the primary objective of the IGY program and evaluation of data obtained in the field of communications. Atmosphere effects, solar energy, ionosphere effects, Faraday fading, auroras, Van Allen radiation, and cosmic noise are included in the discussion.

Frequency Shifts Improve Pulse Communications. J. L. Hollis. *Electronics*, June 19, 1959, pp. 66–69. Discussion of a technique to overcome multipath problems in long-range pulse transmission. The transmitter and the receiver simultaneously shift frequency so that the receiver is sensitive only to the transmission arriving by the shortest path.

Performance Equations for a "Stationary" Passive Satellite Relay (22,000-Mile Altitude) for Communication. Morris Handelsman. *IRE Trans., CS Ser.*, May, 1959, pp. 31–37. 21 refs. Presentation of equations for a satellite used as a passive bounce point for almost hemispherical coverage of the earth for communication purposes. The antenna size and transmitter power for desired signal-to-noise ratio are given for various types of passively-reflecting satellites.

Construction Techniques

Protective Coatings for Missile Printed Circuits. A. E. Hawley and W. E. Weber. *Elec. Mfg.*, June, 1959, pp. 58–62. Discussion of the formulation and characteristics of several coatings specially developed for printed circuits. Epoxy and silicone types appear particularly advantageous. Test procedures are also detailed.

Cooling

Design Plan for Forced-Air Cooling. T. C. Reeves. *Elec. Mfg.*, June, 1959, pp. 63–65, 73.

Magnetic Devices

Permanent Magnet Materials. R. J. Fabian. *Materials in Des. Eng.*, July, 1959, pp. 108–114. Survey of the properties of magnet steels, alnicos, ceramics, and fine particle magnets.

Izmerenie Shiriny Granichnogo Sloia Mezhdu Domenami v Ferromagnetikakh. L. V. Kirenskii and V. V. Veter. *AN SSSR Dokl.*, Mar. 21, 1959, pp. 526–529. In Russian. Description of measurements covering the width of the boundary layer between domains in ferromagnetics.

Analiz Raboty Impul'snykh Magnitnykh Elementov v Beskontaktnykh Ustroistvakh Telemekhaniki. I. V. Prangishvili. *Avtom. i Telemekh.*, Apr., 1959, pp. 473–485. In Russian. Analysis of the operation of magnetic pulse elements with rectangular hysteresis loop in contactless control systems.

Measurement & Testing

Radio-Compass Testing with Small Shielded Enclosures. A. S. Markham. *IRE Trans., ANE Ser.*, Mar., 1959, pp. 4–8.

Power Measurements on Millimetric Valves. H. Weill. *(Le Vide*, No. 67, 1957, pp. 122–127.) *Gt. Brit., RAE Lib. Transl. 812*, Mar., 1959. 14 pp.

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The Gyrovibrator. N. D. Diamantides. *IRE Trans., ANE Ser.*, Mar., 1959, pp. 16–25. Analysis of a new device for measuring angular rate, and presentation of its mechanical and electrical design features. Analytical proofs of three important characteristics of the instrument are given.

Networks, Filters

Korrektsia Nepreryvnoi Sistemy Avtomaticheskogo Regulirovaniia pri Pomoshchi Fil'tra na Elementakh Zapazdyvaniia. Van Sin'-Min'. *Avtom. i Telemekh.*, Apr., 1959, pp. 437–446. 11 refs. In Russian. Presentation of a method of calculation for delay element filters used in the compensation of continuous automatic control systems.

Piezoelectricity

Research on Barium Titanate and Other Ferroelectric Materials for Use as Information Storage Media. Ch. F. Pulvari. *USAF WADC TR 58-657 [AD 209530]*, Sept., 1958. 224 pp. 39 refs.

Power Supplies

Design Study, Power Supply, Alternating Current, with Adjustable Characteristics. S. S. Burns. *USAF WADC TN 59-75 [AD 211774]*, Mar., 1959. 125 pp.

Six Rules for Evaluating CFVS Generators. F. T. DeWolf, E. A. Erdely, E. E. Kolatorowicz, and W. R. Miller. *Space/Aeronautics*, July, 1959, pp. 93, 94, 96–103 (ff.). Review of four basic constant-frequency, varying-speed generation systems. Energy considerations of slip systems, size problems, mechanical contrarotation, electromagnetic field rotation, power flow concepts, and reactive current problems are discussed.

Ekspluatatsiia Istochnikov Energosnabzheniia Samoletov Iak-18 i Iak-11. A. Shabota. *Kryl'ia Rodiny*, Feb., 1959, pp. 20, 21. In Russian. Survey of electrical power supply systems for the Yak-18 and Yak-11 aircraft, and discussion of their operation, maintenance, and failure sources.

Radar

Effect of Surface Reflections on Rain Cancellation of Circularly Polarized Radars. R. McFee and T. M. Maher. *IRE Trans., AP Ser.*, Apr., 1959, pp. 199–201. USAF-sponsored presentation of estimates for the reduction in cancellation of rain reflections due to surface reflections for the case of ground-based radar overlooking the sea.

Radar Performance Degradation in Fog and Rain. H. E. Hawkins and O. La Plant. *IRE Trans., ANE Ser.*, Mar., 1959, pp. 26–30. Derivation of an equation which can be used to (1) predict the performance of any given radar under various meteorological conditions, and (2) compare the performance of radars of different parameters operating under identical meteorological conditions. The combined effects of backscattering and atmospheric attenuation are taken into consideration.

The PAR-Scope: An Oscilloscope Display for Weather Radars. Edwin Kessler, III. *IRE Trans., ANE Ser.*, Mar., 1959, pp. 31–36. 16 refs. Description of the operation and calibration of the PAR-scope. A theoretical performance analysis is made considering the response of the scanning system to spatial variations of average reflectivity and to the rapid fluctuations characteristic of weather echoes.

Reducing Mutual Radar Interference. K. H. Chase and J. L. Pierzga. *Electronics*, July 10, 1959, pp. 39–43. Discussion emphasizing the broad frequency spectrum of the transmitted signal which often extends far beyond its useful bandwidth, thereby being seen by a receiver far removed from the carrier frequency. Remedial measures are suggested.

Using Magnetic Circuits to Pulse Radar Sets. Arthur Krinitz. *Electronics*, July 3, 1959, pp. 42, 43. Description of a pulse generator using a transistor drive and high-permeability, high-saturation flux-density cores. Size and weight reduction are obtained and reliability is increased.

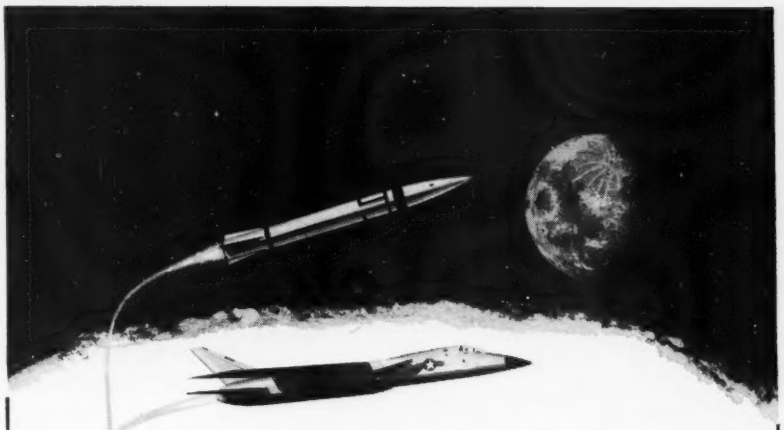
Video Converter Puts Electronic Maps on Radar Scope. B. I. McCaffrey. *Space/Aeronautics*, July, 1959, pp. 143, 144, 147, 148, 150. Description of an electronic map projection system that electronically superimposes a map of tension with prominent natural and man-made features on a plan-position-type display.

Perekhodnye i Ustanovivshiesia Protsessy v Avtomaticheskom Indikatore Dal'nosti. I—Opisanie Raboty Ustroistva i Primenenie Apparata Stupen'chatykh Funktsii dlia Analiza Protsessov v Indikatore. F. M. Kilin. *Avtom. i Telemekh.*, Oct., 1958, pp. 901–916. 13 refs. In Russian. Study of the transient and steady processes in an automatic range finder of a radar station.

Semiconductors

Opredelenie Poverkhnostnoi Provodimosti Poluprovodnikovykh Kristallov Metodom "Klina."

(*Continued on page 104*)



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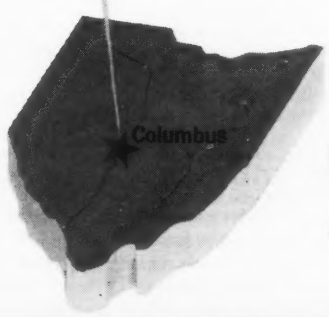

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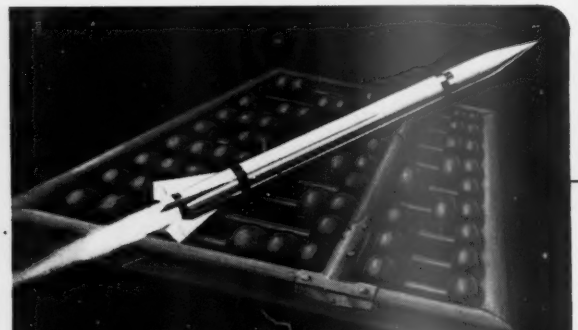
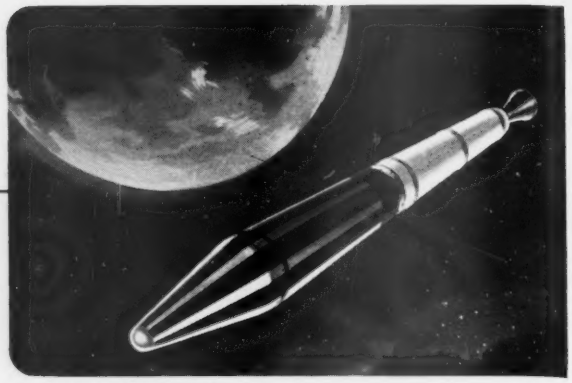
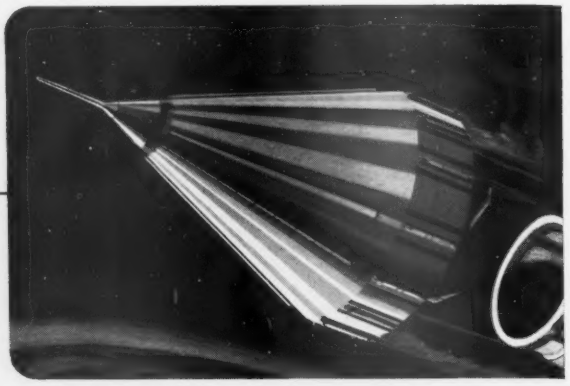
GUIDANCE SYSTEMS . . . both inertial and radio-command types employing new concepts of radar communication have been pioneered at JPL. This guidance system development activity is supported by basic research in all phases of electronics.



COMPUTERS . . . and the application of computing techniques to missile guidance systems have been pioneered by JPL. The Laboratory is now searching for new techniques that will further advance the state of the art in digital guidance components and computer systems.



DATA TRANSMISSION . . . brings news from space via the Explorer series. Explorer III used a tape recorder the size of a cigarette pack capable of transmitting two hours of information in 5 seconds. Electronic payload weight was approximately 11 lbs.



INSTRUMENTATION . . . of the moon probe provided measurement of radiation environment at distances far from the earth. Telemetered data revealed the existence of high intensity radiation. Miniaturization resulted in an instrument payload weighing only 10 lbs.

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Volume 4, Number 9 September, 1959

ACOUSTICS, SOUND, NOISE

METHODS OF FLIGHT VEHICLE NOISE PREDICTION. P. A. Franken and E. M. Kerwin, Jr. Appendix - VIBRATION FREQUENCY CHARTS. J. N. Macduff and R. P. Felgar. USAF WADC TR 58-343 [AD 205776], Nov., 1958. 181 pp. 11 refs. Presentation of detailed engineering procedures for estimating sound pressure levels on or within a flight vehicle. The first steps in the procedure are the estimation of exterior noise levels considering noise sources and the effect of forward speed and altitude. Next the noise transmitting properties of panel, the effect of coincidences, resonances, damping, etc. are included. Finally vehicle geometry is combined with known properties and appropriate corrections to yield interior noises.

AERODYNAMICS, FLUID MECHANICS

Aerothermochemistry, Dissociation, Ablation

CONTRIBUTO ALLO STUDIO DELL'AEROTERMOCHIMICA. Luciano de Socio. Missili, Apr., 1959, pp. 5-22. 11 refs. In Italian. Derivation of basic equations of aerothermochemistry expressed in a system of generalized curvilinear coordinates, covering both dissipative and non-dissipative flows, for a group of reference systems. Includes extension of the Mangler-Pai transformation to the case of axisymmetrical motion of dissipative mixed flows, in the presence of chemical reaction, taking into account the curvature effect (up to the second approximation).

ENERGY TRANSFER IN THE COUETTE FLOW OF A RADIANT AND CHEMICALLY REACTING GAS. Robert Goulard and Madeleine Goulard. Bendix Av. Prod. Div. Appl. Sci. Lab. Paper, Apr., 1959 (revised). 20 pp. 11 refs. Study of radiation phenomena encountered at hypersonic velocities and corresponding high temperatures. The energy fluxes in a radiant medium are determined by solving a system of coupled equations including the integrodifferential equation of radiant energy conservation. The problem of the Couette flow is solved and it is shown that the effect of the "long-range" process of radiation is to smooth out the temperature profiles and relieve the sharp temperature gradients at a cool wall. As a result, a lower value of the total heat flux than calculated by approximate methods is obtained.

Aerothermodynamics

THE COUPLING OF RADIATION AND CONVECTION IN DETACHED SHOCK LAYERS. R. Goulard. Bendix Av. Prod. Div. Appl. Sci. Lab. Paper, Apr. 14, 1959. 11 pp. 11 refs. Study of the effects of fluid energy loss on the energy distribution in the shock layer and on the convective and radiative fluxes at the wall. A nondimensional parameter is shown to govern the resulting coupling between radiative and convective fluxes. The first approximation which consists in assuming a constant stagnation temperature layer is shown to be acceptable for most re-entry problems, except for very large vehicle dimensions or velocities.

THE APPLICATION OF CONSTANT PROPERTY SOLUTIONS TO MASS TRANSFER COOLING CALCULATIONS. Appendix A - ALTERNATE DERIVATION OF THE PRESENT METHOD FOR CALCULATING THE EFFECTS OF FOREIGN GAS INJECTION - LAMINAR CONSTANT PRESSURE FLOW. Appendix B - PROPERTY VALUES. Appendix C - ANALYSIS CONSIDERING A STEP FUNCTION IN THE PROPERTIES. C. J. Scott. Minn. U. Inst. Tech. RAL Eng. Memo. 76 (AFOSR TN 59-201) [AD 211527], Dec., 1958. 32 pp. 36 refs. Development of simple transformation relations for applying the results of constant property boundary-layer solutions to the calculation of mass-transfer cooling problems using foreign gas effusion. Laminar con-

stant pressure, laminar stagnation, and turbulent constant pressure flows are studied. A reference-concentration of four-tenths of the wall concentration was used in evaluating the properties. Comparisons are made with currently available exact theoretical solutions in order to assess the value of the method as a means for extrapolating to conditions not covered by the available solutions. Good correlation results between present calculations and exact analyses if the wall concentrations are estimated accurately.

COMBINED FORCED AND FREE CONVECTION IN A BOUNDARY LAYER FLOW. E. M. Sparrow, R. Eichhorn, and J. L. Gregg. Phys. Fluids, May-June, 1959, pp. 319-328. Analysis considering the combined forced and free convection flow and heat transfer about a nonisothermal body subjected to a nonuniform free stream velocity. Similar solutions for the laminar boundary-layer equations are found to exist when the free stream velocity and surface temperature vary. Extensive numerical solutions of the transformed boundary-layer equations are carried out for the cases of uniform wall temperature and uniform wall heat flux for a Prandtl Number of 0.7. Results are reported for heat transfer, shear stress, and velocity and temperature fields. Criteria are given for cataloguing flows as purely forced, purely free, and mixed.

Boundary Layer

DECOLLEMENT SUR UNE AILE DELTA PLACEE SANS INCIDENCE DANS UN ECOULEMENT LAMINAIRE INCOMPRESSIBLE. E. A. Eichelbrenner, P. Laval, and H. Werlé. La Recherche Aéronautique, May-June, 1959, pp. 11-14. In French. Extension of the method for calculating three-dimensional laminar boundary layers to the case of a delta wing without incidence. The theoretical flow and, in particular, the separation line are compared with the experimental flow diagram representing the results of visualization tests in a hydrodynamic tunnel.

SIMILAR TEMPERATURE BOUNDARY LAYERS. Dragutin Stojanović. J. Aero/Space Sci., Sept., 1959, pp. 571-574, 591. Presentation of conditions for the existence of similar temperature boundary layers in both two- and three-dimensional cases with constant and variable wall temperatures. The general condition is that with or without viscous heating, and with constant wall temperature, conditions for the existence of similar velocity boundary layers are at the same time the conditions for the existence of similar temperature boundary layers. Numerical solutions are given for the nondimensional temperature distributions function and the nondimensional temperature gradient at the wall for several Prandtl Numbers in the case of rotating flow over an infinite plate at rest.

BERECHNUNG VON REIBUNGSSCHICHTEN MIT SCHWACHER SEKUNDÄRSTRÖMUNG NACH DEM IMPULSVERFAHREN. Ernst Becker. ZFW, June, 1959, pp. 163-175. 16 refs. In German. Derivation of a method of approximation which is based on the Gruschwitz momentum theorem and is applicable to the study of laminar or turbulent boundary layers with a weak secondary flow. The momentum equations are appropriately modified, and the method of computation developed by Holstein and Bohlen is introduced into the derivation of formulas for laminar flow.

EFFECT OF STANDING VORTEX ON FLOW ABOUT SUCTION AEROFOILS WITH SPLIT FLAPS. P. Mandl. Canada, NRC Aero. Rep. LR-239, Jan. 14, 1959. 47 pp. Extension of the theory of flow about airfoils to cover the standing vortex within the angle between the airfoil and the flap. The strength and the equilibrium position of the vortex are calculated by applying the Kutta condition both at the trailing edge of the airfoil and at the tip of the flap. It is shown that the standing vortex increases the lift coefficient, thus widening the discrepancy between theory and experiment observed earlier. This discrepancy is believed to be due to flow separation near the leading edge. Stream lines are calculated for a particular configuration of airfoil and split flap. The calculated flow pattern indicates the existence of a cavity which is mainly influenced by the vortex and the sink. The streamlines inside and outside the cavity agree well with experiment.

LAMINAR BOUNDARY LAYER WITH SUCTION AND INJECTION. R. J. Gribben. Phys. Fluids, May-June, 1959, pp. 305-318. Study introducing the following assumptions: a heat insulated body, a Prandtl Number of unity, and a linear temperature-viscosity relation. The axisymmetric equations governing a given high-speed compressible flow are reduced to the equations describing an incompressible two-dimensional flow past a flat plate with a determinable main stream and normal wall velocity distribution. The results are applied to the supersonic flows over a cone with wall velocities proportional (1) to the first power and (2) to the inverse half-power of distance along a generator when the resulting incompressible flows are known. Also, the flow near the tip of a general slender body of revolution in supersonic flow with constant wall velocity is obtained by solving numerically the equations of the correlated incompressible flow. It is also shown that, if the assumption of an insulated body is discarded, a given high-speed compressible flow may still be correlated with a determinable low-speed compressible flow.

BOUNDARY LAYER TRANSITION ON A 10- DEGREE CONE IN THE N.A.E. 30- x 16-INCH WIND TUNNEL. J. A. van der Bliek. Canada, NAE LR 232, Nov., 1958. 13 pp. Discussion of tests using fluorescent lacquer, French chalk and kerosene, and lampblack and kerosene

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for flow visualization. The transition Reynolds Number was determined at Mach Numbers from 1.5 to 2. The results obtained with the three methods are in good agreement and show the transition Reynolds Number to be between 2.3×10^6 and 3.3×10^6. The removal of high drag screens from the intake to the wind tunnel contraction increased the turbulence in the working section in such a way that the boundary layer on the cone became practically entirely turbulent.

ANOTHER UNSTEADY TURBULENT BOUNDARY LAYER. Hendrik Tennekes. Johns Hopkins U. Dept. Aero. Rep. (AFOSR TN 59-600) [AD 217177], May, 1959. 43 pp. 10 refs. Comparison of data obtained by Karlsson for a zero mean pressure gradient turbulent boundary layer subjected to sinusoidal free-stream oscillations with the experimental results of Lighthill for the corresponding laminar layer. In order to determine the linearity of response, the boundary layer is subjected to another free stream transient of the simple step function type. A preliminary discussion of the response of the turbulent boundary layer to this transient is given, and a simple electronic analogue computer for linear synthesis is described.

FLUCTUATION MEASUREMENTS IN A SUPERSONIC TURBULENT BOUNDARY LAYER. A. L. Kistler. Phys. Fluids, May-June, 1959, pp. 290-296. Presentation of hot-wire measurements of the fluctuations in turbulent, constant-pressure boundary layers at Mach Numbers of 1.72, 3.56, and 4.76 and a Reynolds Number based on momentum thickness of about 30,000. The distribution of the static-temperature fluctuation levels through the boundary layer is approximately similar at the various Mach Numbers, and the levels are proportional to the mean static-temperature difference across the boundary layer. A decrease in the velocity fluctuation levels is observed as the Mach Number is increased. There is a high negative correlation between the velocity and temperature fluctuations at all Mach Numbers.

Flow of Fluids

NONEQUILIBRIUM FLOW OVER A WAVY WALL. W. G. Vincenti. Stanford U. Dept. Aero. Eng. SUDAER 85, Mar., 1959. 29 pp. 10 refs. Derivation of a small-disturbance solution for the steady two-dimensional flow over a sinusoidal wall of an inviscid gas in vibrational or chemical nonequilibrium. The results are based on a single, linear, third-order partial differential equation playing the same role as the Prandtl-Glauert equation in equilibrium flow. The solution is valid throughout the range from subsonic to supersonic speeds and for all values of the rate parameter from equilibrium to frozen flow. The results illustrate some of the properties of nonequilibrium flow, such as the occurrence of pressure drag at subsonic speeds and the absence of the discontinuous phenomena that characterize the Prandtl-Glauert theory when the flow changes from subsonic to supersonic.

DRAG MEASUREMENTS ON AGARD MODEL "A" IN THE N.A.E. 30- x 16-INCH WIND TUNNEL AND COMPARISON WITH OTHER DATA. J. A. van der Bliek. Canada, NAE LR 233, Nov., 1958. 14 pp. 16 refs. Description of tests conducted on a model constructed of two halves of solid steel, of which one is used as a half model. The zero-lift drag was measured at Mach Numbers from 0.4 to 2.0 over a Reynolds Number range from 2.5 to 4.8×10^6. The turbulence level was indicated by means of transition data on a 10-degree cone. A comparison with data obtained in other experiments shows that, at supersonic speed, the transition Reynolds Number for a 10-degree cone is approximately the same as that for the parabolic body of revolution.

EXPERIMENTAL STUDIES ON THE HYPERSONIC FLOW PAST PLANE, CONVEX AND CONCAVE WEDGES. Chul-Soo Kim. Phys. Soc. Japan J., June, 1959, pp. 827-837. 18 refs. Investigation of the viscous-inviscid interaction at the leading edge of a body in accelerating or decelerating hypersonic flow. Optical methods and X-ray techniques used to measure the flow field and the air density near the leading edge, respectively, are described. The results are presented for a flat plate, including pressure distribution, boundary layer thickness, and shock wave location; and for wedges, covering the boundary layer growth, the effect of the leading edge bluntness on boundary layer growth, and the pressure distributions.

DESIGN OF MISSILE BODIES FOR MINIMUM DRAG AT VERY HIGH SPEEDS - THICKNESS RATIO, LIFT, AND CENTER OF PRESSURE GIVEN. T. Strand. J. Aero/Space Sci., Sept., 1959, pp. 568-570. Application of Lees' modified Newtonian flow theory to develop a procedure for the design of minimum drag bodies of revolution. It is shown that the optimum body shape is independent of lift. Center of pressure location, however, exerts a powerful influence on both the shape of the body and on the drag coefficient at zero lift.

AN EXTENSION OF THE LINEARIZED CHARACTERISTICS METHOD FOR CALCULATING THE SUPERSONIC FLOW AROUND ELLIPTIC CONES. Anthony Martellucci. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 517 (AFOSR TN 59-632), June, 1959. 51 pp. 12 refs. Application of Ferri's method of characteristics to determine the surface pressure distribution. The method can also be used for cases of large angles of attack, provided that the elliptic body geometry is specified so as not to modify the cross section. Experimental results obtained for several conical bodies are presented. The surface pressure distribution obtained by means of the modified method of characteristics is in

reasonable agreement with experiment over the Mach Number and semidiameter ratio range investigated.

APPROXIMATE SOLUTIONS FOR SUPERSONIC FLOW OVER WEDGES AND CONES. A. G. Hammitt and K. R. A. Murthy. Princeton U. Dept. Aero. Eng. Rep. 449 (AFOSR TN 59-304) [AD 213088], Apr., 1959. 20 pp. Presentation of simplified formulas for both oblique shock and conical flow providing good approximations to the exact solutions. The relations lead to simple and accurate results over a wide range of Mach Numbers and specific heat ratios and are also useful as analytical representations in cases where exact solutions are not available.

OBTEKANIE KONICHESKIKH TEL PRI DVIZHENII GAZA S BOL'SHOI SVERKHZVUKOVOI SKOROST'IU. A. L. Gonor. AN SSSR Otd. Tekh. Nauk Izv. Mekh. i Mashinostr., Jan.-Feb., 1959, pp. 34-40. In Russian. Study of the supersonic flow of gas around conical bodies using previously derived analytical approach for the development of the general theory. The boundary conditions used in the calculation are stated and a solution is derived for the case of plane triangular wings (apex angle 2β) and for elliptical cones. Such aspects as the pressure over the body, the shock wave, and the effect of thickness variation are covered.

HYPERSONIC STUDIES OF BLUNT UNSWEPT WINGS. I. E. Vas and S. M. Bogdonoff. Princeton U. Dept. Aero. Eng. Rep. 450 (USAF WADC TN 59-127) [AD 214623], Apr., 1959. 73 pp. 21 refs. Investigation of pressure distribution and shock shapes of two-dimensional unswept blunt surfaces conducted in a helium tunnel at Mach Numbers between 11 and 19 and at angles of attack of $\pm 10^{\circ}$. The tests were carried out at stagnation pressures between 1,000 and 1,500 psia, and the Reynolds Number per in. ranged from 10^6 to 0.63×10^6. It is found that at high leading edge Reynolds Numbers the pressure distributions are primarily determined by the inviscid flow, and a simple correlation of all results for the Mach Number and angle of attack range was found. The effect of the leading edge shape is also discussed.

OSCILLATIONS IN PLASMA. II. Shoji Kojima, Kiyoe Kato, Shigeo Hagiwara, and Ri'ichi Matsuzaki. Phys. Soc. Japan J., June, 1959, pp. 821-827. Study of the origin of plasma-electron oscillations having slightly different frequencies, generated simultaneously in a hot cathode discharge. The oscillations are detected by means of a probe inserted into the tube or through a Yagi antenna placed on the outside. The experimental procedure is described in detail, and the results are presented for (a) oscillations generated by the convergent beam in the central section of the tube and (b) those generated by the divergent beam near the wall of the tube. A middle frequency oscillation observed at the periphery of the convergent beam is also mentioned.

FURTHER RESULTS ON THE FLOW OF A CONDUCTING FLUID PAST A MAGNETIZED SPHERE. G. S. S. Ludford and J. D. Murray. U. Md. Inst. Fluid Dynamics & Appl. Math. TN BN-174 (AFOSR TN 59-648), June, 1959. 9 pp. Analysis considering the steady flow of an incompressible, inviscid, conducting fluid past a sphere of arbitrary conductivity in which there is an arbitrary axially symmetric magnetic distribution. It appears that the singularity in the vorticity can only be absent when the undisturbed magnetic field vanishes at the front stagnation point. Explicit formulas for the drag are given in terms of coefficients defining the distribution; the drag is the same for image distributions with respect to the plane $\theta = \pi/2$. As an example the drag is computed due to an off-center dipole and is found to be larger than for a center dipole of the same moment.

CHARACTERISTIC MANIFOLDS IN THREE-DIMENSIONAL UNSTEADY MAGNETOHYDRODYNAMICS. R. S. Ong. Phys. Fluids, May-June, 1959, pp. 247-251. Application of a technique developed in the general theory of discontinuities to the basic equations of unsteady magnetohydrodynamics in order to find the conditions to be satisfied by the discontinuities in the derivatives of the significant flow and magnetic field parameters. With the aid of relations satisfied by the jumps in the derivatives of the parameters the various characteristic manifolds are found. Finally, it is shown that these manifolds are hypersurfaces along which small disturbances and weak shocks are propagated.

ON THE CALCULATION OF EDDY VISCOSITY AND HEAT TRANSFER IN A TURBULENT BOUNDARY LAYER NEAR A RAPIDLY ROTATING DISK. D. R. Davies. Quart. J. Mech. & Appl. Math., May, 1959, pp. 211-221. Determination of the distribution of the radial component of Reynolds shear stress by integration of the equations of mean flow, the validity of the von Kármán velocity profiles being assumed. The distribution of eddy heat diffusivity is then evaluated by applying Reynolds analogy in a thin region of flow very near the surface of the disc, and using the approximate similarity of the radial component of disc flow and flat-plate flow to extend the results through the remainder of the inner part of the boundary layer (about 16% of the layer thickness). The methods of Davies and Bourne are then applied to evaluate, in the case of air, the rate of heat transfer from the disc, when the surface is kept at constant temperature.

SHOCK WAVE-TURBULENCE INTERACTION, INVESTIGATIONS IN A SHOCK TUBE. J. E. Werner. Johns Hopkins U. Dept. Aero. Rep.

(AFOSR TR 59-46) [AD 214847], May, 1959. 177 pp. 15 refs. Theoretical and experimental investigation of various aspects of the shock-turbulence interaction problem, including the model of a cellular vortex field with a discrete front converted through a shock wave. Expressions are derived for the unsteady pressure disturbance on the downstream face of the shock, and the displacement of the shock wave itself as the vortex field is carried through it by the mean flow. The interaction of a shock with a random velocity fluctuation field is also considered and the relationship between pressure fluctuation and shock displacement is also studied. The pressure fluctuation level is found to depend on shock displacement, turbulence scale, and turbulence intensity. Includes comparison between measured and theoretical results, study of shock wave reflection from a grid placed in a shock tube, and development of a one-dimensional theory to predict reflection for the case in which the flow is not yet sonic at the grid - i.e., below choking.

TWO-DIMENSIONAL GASEOUS DETONATIONS: VELOCITY DEFICIT. J. A. Fay. Phys. Fluids, May-June, 1959, pp. 283-289. 15 refs. ONR-supported analysis of previously determined experimental results showing the measured velocity of gaseous detonation waves to be less than that predicted by the Chapman-Jouguet plane wave theory. The velocity deficit (difference between theoretical and measured velocities) was found to vary inversely with the tube diameter and initial pressure. A quantitative explanation of this effect is advanced by determining the growth of the viscous boundary layer on the tube wall and its effect upon the flow in the reaction zone of the detonation front. It is proposed that the boundary layer displacement effect within the reaction zone produces a uniform flow divergence throughout the detonation front. The velocity deficit due to this two-dimensional flow is determined, using measured values of reaction zone thickness.

ON THE SPEED OF SOUND IN AIR. R. A. Gross and C. L. Eisen. Phys. Fluids, May-June, pp. 276-279. 10 refs. AFOSR-supported calculation and comparison of the frozen and equilibrium sound speeds behind a normal shock in air. In a high temperature gas, the speed of sound depends upon the chemical composition, sound frequency, and chemical reaction rates. Two limiting sound speeds are normally distinguished: that of "frozen" or constant chemical composition, and the "equilibrium" sound speed. Equations to determine these two sound speeds are presented for a nitrogen-oxygen system, and numerical data are given for speeds up to Mach 20.

Internal Flow

THEORETICAL AND EXPERIMENTAL CASCADE FLOW INVESTIGATIONS AT HIGH SUBSONIC MACH NUMBERS. (PRESSURE DISTRIBUTIONS AND WAKE MEASUREMENTS). U. Hopkes. DFL Inst. Aero. Rep. 59/21, June 26, 1959. 55 pp. 18 refs. USAF- sponsored experimental investigation of two-dimensional cascades with different solidity ratios and blade angles using two different blade profiles (NACA 0010 and NACA 8410). The measurements are made at a constant Reynolds Number and at varying Mach Numbers up to the choking Mach Number and cover the following: pressure distribution on the blade, loss coefficient, deflection of flow, and static pressure difference across the cascade. It is shown that the static pressure difference varies with the Mach Number while the loss coefficient and the deflection are approximately constant up to the critical Mach Number. A comparison between experimental pressure distributions and theoretical calculations based on the Prandtl-Glauert rule and the Kármán-Tsien rule is found to yield satisfactory results.

UNTERSUCHUNG DER SPALTVERLUSTE VON TURBINENLEITRÄDERN MIT BEWEGTER SPALTWAND. J. Rehbach. DFL Inst. Aero. Bericht No. 90, Apr., 1959. 73 pp. 24 refs. In German. Investigation performed to determine whether the slot losses occurring in a plane cascade with steady walls could be extended to the case of losses on rotating cascades with relative motion between blade and wall. Measurements were made on axial cascades by rotating the hub wall at different speeds, while the blades were maintained at rest. Results show that for practical applications the relative motion between the blade tip and wall clearance has little effect on the slot losses.

REPRESENTATION CONFORME DU POLYGONE CIRCULAIRE; APPLICATION A L'ETUDE DE L'ECOULEMENT PLAN D'UN FLUIDE COMPRESSIBLE. Robert Legendre. France, ONERA Pub. 94, 1959. 73 pp. In French. Study covering the conformal representation of a circular polygon and application to the case of plane flow of a compressible fluid, using cascade flow as an illustrative example. Two methods for studying the conformal transformation are evaluated and a study is made of: (a) the Euler functions involved in the description of the flow fields of an incompressible fluid, (b) the problem of standardization for the case of a circular triangle, and (c) the problem of compressible fluid mechanics of interest in the turbomachine research.

SUPERSONIC NOZZLE FLOW WITH A REACTING GAS MIXTURE. P. P. Wegener. Phys. Fluids, May-June, 1959, pp. 264-275. 17 refs. USAF-Army-sponsored investigation of stationary supersonic nozzle flow of a reacting gas mixture of nitrogen tetroxide and dioxide carried at low concentration in nitrogen. A judicious choice of supply conditions and nozzle geometry made it possible to produce flows either in chemical equilibrium or in states between this and the frozen flow. The flow is determined from pressure and

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area measurements and, by applying an equation for the reaction mechanism, rate constants of recombination can be found. Experiments with stationary oblique shocks led to a determination of the dissociation rate constant.

EFFECT OF JET MIXING ON THE ANNULAR JET. H. R. Chaplin. US, Navy Dept., David Taylor Model Basin, Aero Rep. 953 (TED TMB AD-3242), Feb., 1959. 28 pp. Presentation of an approximate theoretical approach to the effect of jet mixing on the annular jet. The two-dimensional problems of the annular jet within and outside of ground effect are treated in detail. Augmentation factor and critical altitude are found to depend on nozzle area, pressure, and temperature ratios, in addition to the parameters affecting the nonmixing annular jet. The results indicate that the mixing has important adverse effects on annular jets using narrow nozzles and high pressure ratios.

INTERACTION OF A TWO-DIMENSIONAL INVISCID INCOMPRESSIBLE JET FACING A HYPERSONIC STREAM. S. H. Lam. Princeton U. Dept. Aero. Eng. Rep. 447 (AFOSR TN 59-274) [AD 212708], Mar., 1959. 31 pp. 14 refs. Investigation of a two-dimensional blunt body with a flat plate spike and coolant injection in order to determine the position of the stagnation point, the shape and position of the interface, and the effects on drag due to injections. Assuming that the jet flow directly opposing the oncoming stream has a common stationary stagnation point with the hypersonic shock layer, the free stream line case and the attached-flow case are studied. The analysis is carried out on the basis of the modified Newtonian pressure formula for the jet-shock layer interface.

STATIC LIFT CHARACTERISTICS OF JET SLOTS - A CLARIFYING STUDY OF THE EXTERNAL EJECTOR. M. F. Gates. Hiller Aircraft Adv. Res. Div. Rep. ARD-213, Oct. 15, 1958. 82 pp. 29 refs. Evaluation of the external ejector in both two- and three-dimensional configurations in order to determine the thrust augmentation potentialities of the phenomenon. The results of the program together with previously obtained data indicate that static thrust is not possible with the external ejector. It was found, however, that ideal turning efficiencies as high as 88% are possible. In both two- and three-dimensional configurations, the turning efficiency increased with increasing nozzle slot height (σ) which was determined by breakaway in the two-dimensional tests and by insufficient air supply in the three-dimensional ones. Performance data and surface pressure survey are presented for both configurations. Flow visualization by means of smoke streams is discussed.

Jet Flaps & Wings

LOW-SPEED INVESTIGATION OF BLOWING FROM NACELLES MOUNTED INBOARD AND ON THE UPPER SURFACE OF AN ASPECT-RATIO-7.0, 35° SWEPT WING WITH FUSELAGE AND VARIOUS TAIL ARRANGEMENTS. T. R. Turner, E. E. Davenport, and J. M. Riebe. US, NASA Memo. 5-1-59L, June, 1959. 42 pp. Wind-tunnel investigation to determine the static longitudinal and aerodynamic characteristics of a high-wing transport model equipped with upper surface nacelles and with various partial-span inboard jet-flap and horizontal-tail arrangements. Results indicate that blowing from the upper surface nacelle over the flaps gave lift increases greater than the lift component of the jet reaction. Large diving-moment coefficients were obtained at the higher lift and momentum coefficients. Static longitudinal instability of the model with the conventional tail decreased with tail height.

Performance

A QUANTITATIVE ANALYSIS OF THE CHARACTERISTICS AND LIMITATIONS OF AERODYNAMIC FLIGHT WITHIN THE ATMOSPHERE. II - LIMITATIONS. W. Ch. Walter. Aero/Space Engrg., Sept., 1959, pp. 63-66. Analysis of the characteristics of the aerodynamic flight regime show that centrifugal lift has a profound influence on the limitations of both cruising and aerospace vehicle flight, and that the effects of the variation of the earth's gravitational acceleration are negligible in this area. It is evident that in order to fly a winged vehicle in efficient cruising flight close to the upper limits of the cruising vehicle flight regime, the vehicle must be designed for low wing loading. Flight at low angles of attack is indicated due to the limitations on optimum lift coefficient. Above 100,000 ft. a small increase in altitude is accompanied by a large increase in speed required for cruising flight at that altitude.

Stability & Control

SOME INSTABILITIES ARISING FROM THE INTERACTIONS BETWEEN SHOCK WAVES AND BOUNDARY LAYERS. N. C. Lambourne. (NATO AGARD 7th Structures & Materials Panel, Rome, Mar. 24-Apr. 3, 1958.) NATO AGARD Rep. 182, Apr., 1958. 40 pp. 40 refs. Survey of available data on flow fluctuations and instabilities arising from shock-induced separation in the flow over lifting surfaces and wings. The effect of this phenomenon on the oscillatory behavior of airfoils and control surfaces is also discussed. An investigation of the role of shock-induced separation in the instability of a control surface is also discussed.

Wings & Airfoils

A METHOD FOR SOLVING THE SUBSONIC PROBLEM OF THE OSCILLATING FINITE WING WITH THE AID OF HIGH-SPEED DIGITAL COMPUTERS. V. J. E. Stark. SAAB TN 41, Dec.16, 1958. 36 pp. 15 refs. Formulation of the line-

arized problem of the finite wing in subsonic flow in terms of the integrated acceleration potential. A method for computing the set of downwash functions pertaining to the set of functions for the approximation of the pressure distribution is developed. The numerical results presented for a rectangular wing of aspect ratio 3 in incompressible flow are obtained through approximating the given downwash by means of the least square method. The procedure is particularly suited for the calculation of wings with unswept trailing edges when treated in reverse flow.

CHORDWISE PRESSURE DISTRIBUTIONS OVER SEVERAL NACA 16-SERIES AIRFOILS AT TRANSONIC MACH NUMBERS UP TO 1.25. Ch. L. Ladson. US, NASA Memo. 6-1-59L, June, 1959. 285 pp. Results of a two-dimensional wind-tunnel investigation conducted in the Langley airfoil test apparatus to extend the data on thin and moderately thick 16-series airfoils incorporating camber throughout the transonic speed regime. The airfoil thicknesses were 4, 6, 9, and 12% of the chord and the design lift coefficients 0, 0.2, and 0.5. The tests ranged in Reynolds Number from 2.4×10^6 to 2.8×10^6 and in angle of attack from -10^o to 12^o. Chordwise pressure distributions and schlieren photographs are presented without analysis. The results are used in the study of helicopter blades for achieving higher forward flight speeds.

RING AIRFOIL THEORY - PROBLEMS OF INTERFERENCE AND BOUNDARY LAYER. Johannes Weissinger. Karlsruhe Tech. Hochsch. Inst. Angew. Math. Rep. (AFOSR TN 59-226) [AD 211809], Jan., 1959. 105 pp. 19 refs. Study of the interference of the ring airfoil with a strut. The theory of ring-body interference is extended to slender bodies of finite length whose diameter is small compared with the ring diameter. The lift of the body and the wing, and the pitching moment of the body are determined; explicit formulas and numerical results are given for ellipsoids of revolution. In boundary-layer theory the methods used in previous studies are improved by introducing the Mangler transformation and some minor refinements. The three-dimensional laminar boundary layer, in particular the streamlines on the wall and the line of separation, are investigated by a method similar to that used by Eichelbrenner and Oudart for ellipsoids.

SUPERSONIC AND MOMENT-OF-AREA RULES COMBINED FOR RAPID ZERO-LIFT WAVE-DRAG CALCULATIONS. Appendix A - DIMENSIONLESS ZERO-LIFT WAVE-DRAG EQUATIONS. Appendix B - CONCEPT OF SHEARED CONFIGURATIONS. Appendix C - MOMENTS AND LENGTHS FOR SHEARED WINGS AND TAILS. Appendix D - SAMPLE CALCULATIONS. Appendix E - EVALUATION OF THE INTEGRAL FUNCTIONS FOR AIRFOIL SECTIONS WITH NONANALYTIC THICKNESS DISTRIBUTIONS. L. L. Levy, Jr. US, NASA Memo. 4-19-59A, June, 1959. 68 pp. Calculation of the total zero-lift wave drag of a configuration by a new method considering the sum of the wave drag of each component alone plus the interference between components. In calculating the separate contributions, each component or pair of components is analyzed over the smallest allowable length in order to improve the convergence of the series expression for the wave drag. The accuracy of the present method is evaluated by comparing the total zero-lift wave-drag solutions for several simplified configurations obtained by the present method with solutions given by slender-body and linearized theory. The results of the evaluation indicate that the wave-drag solutions for simplified configuration which can be obtained by the present method differ from solutions given by slender-body and linearized theory by less than 6%.

THE VELOCITY POTENTIAL ON TRIANGULAR AND RELATED WINGS WITH SUBSONIC LEADING EDGES OSCILLATING HARMONICALLY IN SUPERSONIC FLOW. Appendix I - THE THEORY OF THE METHOD. Appendix II - THE SOLUTION OF THE INTEGRAL EQUATIONS. Appendix III - SOME SUBSIDIARY EQUATIONS. Appendix IV - THE EVALUATION OF SOME INTEGRALS. D. E. Davies. Gt. Brit., RAE Rep. Struc. 244, Feb., 1959. 103 pp. Application of the method developed by Watkins and Berman to the calculation of the velocity potential. A symmetric mode of oscillation is considered which is represented by a polynomial expression in the coordinates or the points of the wing. This polynomial expression is of higher degree than those derived previously. The results enable the first few terms of a power series in frequency for the velocity potential to be obtained.

AEROELASTICITY

PROBLEMS IN THE DYNAMICS OF ELASTIC SYSTEMS UNDER INITIAL STRESS. Yih-O Tu and George Handelman. Rensselaer Polytech. Inst. Dept. Math., RPI MathRep. 25 (AFOSR TN 59-406) [AD 214503], May 8, 1959. 74 pp. 24 refs. Formulation of the eigenvalue problems associated with vibration and stability of beams under initial axial stress and flat plates under initial plane stress from variational principles for general structural members. The form of the ordinary differential equation for the vibration of beams is presented. Upper bounds may be obtained from minimum principles, in particular Rayleigh quotients. Comparison theorems providing lower bounds are established for this particular type of eigenvalue problem. The ordinary Southwell method for lower bounds of the first eigenvalue can be applied directly for the case $\psi(x) = 0$ for all x throughout the entire length of the beam; similar methods are formulated and proved accordingly for other cases. The Schwarz iteration method can also be used to find upper and lower bounds for the first eigenvalue. Approximate solutions can be obtained by Rellich's per-

turbation theory. Perturbation solutions are carried out for a thin, long, flat plate simply supported on all edges and subjected to parabolic temperature distribution. Numerical results indicate the existence of critical loads.

MODIFIED MATRIX METHOD FOR CALCULATING STEADY-STATE SPAN LOADING ON FLEXIBLE WINGS IN SUBSONIC FLIGHT. Appendix - AERODYNAMIC-INFLUENCE COEFFICIENTS FROM TABLES OF DOWNWASH FACTOR. P. A. Gainer and W. S. Aiken, Jr. US, NASA Memo. 5-26-59L, June, 1959. 62 pp. Presentation of a method using tables of downwash factors to find the necessary aerodynamic-influence coefficients for the application of lifting-line theory. Explicit matrix equations of equilibrium are converted into a matrix power series with a finite number of terms by utilizing certain characteristic properties of matrices. The number of terms in the series is determined by a trial-and-error process dependent upon the required accuracy of the solution. Spanwise distribution of angle of attack, airload, shear, bending moment, and pitching moment are obtained as functions of qm_R, where q denotes the dynamic pressure and m_R is the lift-curve slope of a rigid wing.

SUPERSONIC PANEL FLUTTER OF A CYLINDRICAL SHELL OF FINITE LENGTH. S. L. Strack and Maurice Holt. Brown U. Div. Appl. Math. Rep. (AFOSR TN 59-547) [AD 216693], May, 1959. 56 pp. 20 refs. Determination of panel flutter characteristics for different dimensions and modes of support of the shell and various undisturbed free-stream Mach Numbers. Based on the theory developed by Stepanov, exact expressions for the aerodynamic forces are derived to cover supersonic as well as hypersonic flow. The Goldenveizer equation is used for the motion of the cylinder and a quasi-steady approach is adopted. The formulation of the equations and justification of various approximations made throughout the study are also discussed. The results obtained are compared with those of earlier calculations.

COMPUTERS

REPRESENTATION DIRECTE PAR ANALOGIE RHEOELECTRIQUE DES GRADIENTS DE FONCTIONS HARMONIQUES EN DOMAINE PLAN LIMITE OU ILLIMITE. Guy Renard. France, Min. de l'Air NT 78, 1958. 115 pp. 13 refs. SDIT, 2 Av. Porte-d'Issy, Paris 15, Frs. 2,107. In French. Description of a method using the rheoelectric analogy for determining directly the gradients of harmonic functions in the finite or infinite domains. Includes analysis of various possible and available solutions; description of experiments; evaluation of the advantages of the method for studying airfoil profiles; application to specific cases, including those of a symmetrical NACA profile with zero incidence, cascade flow, and flow around obstacles; and such problems as determining the moduli of a conformal transformation simplified by the use of logarithmic potentials and studying the temperature fields.

RESOLUTION PAR ANALOGIE ELECTRIQUE D'EQUATIONS AUX DERIVEES PARTIELLES DU QUATRIEME ORDRE INTERVENANT DANS DIVERS PROBLEMES D'ELASTICITE. Jean Boscher. France, Min. de l'Air PST 348, 1958. 130 pp. 34 refs. SDIT, 2, Av. Porte-d'Issy, Paris 15, Frs. 2,251. In French. Application of electric analogy methods to the solution of fourth-order partial differential equations encountered in various elasticity problems. A detailed description is given of various methods used to determine (a) the Airy function governing the state of stress in an elastic medium; (b) the flexural moment and the deformation function for beams, and (c) the deformation function for homogeneous elastic plates. Various examples illustrate the applicability and the accuracy of the procedure.

FUELS & LUBRICANTS

THE USEFUL LIFE OF SOLID PROPELLANTS AT VERY HIGH TEMPERATURES. I. M. Visnov. (ASME-ARS Av. Conf., Dallas, Mar. 17-20, 1958.) ARS J., July, 1959, pp. 500-505. Evaluation of the thermal stability of propellants for cartridge actuated devices operating at elevated temperatures associated with supersonic speeds, and establishment of their auto-ignition hazard zones. The study includes experiments with various propellant types for determining the rate of controlled decomposition into specified volumes of gas, and an investigation of the propellant life under extremes of exposure, considering such factors as: location of devices, extension of temperature range, repetition of high temperature exposures (recycling), and limitations for protection of propellant powered devices.

RECENT ADVANCES IN SOLID PROPELLANT GRAIN DESIGN. J. A. Vandenkerckhove. ARS J., July, 1959, pp. 483-491. 31 refs. Survey of data on end-burning, side-burning, and noncylindrical grains and consideration of such factors as internal ballistics, including long and short burning times; similarity rules; overall grain dimensions; and fundamentals of design. Mechanical and thermal stresses, as well as stress concentrations are discussed, and design charts are presented.

INSTRUMENTS

Pressure Measuring Devices

FREE-FLIGHT EXPERIMENTS ON THE MEASUREMENT OF FREE-STREAM STATIC PRESSURE AT TRANSONIC SPEEDS WITH PARTICULAR REFERENCE TO THE Mk. 9 PI-

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TOT-STATIC HEAD. C. Kell. Gt. Brit., RAE TN Aero. 2598, Dec., 1958. 18 pp. Survey of free-flight measurements of ambient static pressures ahead of bodies of revolution with noses of different shapes at Mach Numbers between 0.8 and 1.4. The results indicate the minimum distances ahead of blunt-nosed bodies at which the errors in static pressure measurements are small enough to be acceptable. A description covering errors introduced by the static-pressure measuring heads themselves, tests on the standard Mk.9 pitot-static head, and results from this and other types of head are also included.

MISSILES, ROCKETS, SPACE CRAFT

JUMP DUE TO AERODYNAMIC ASYMMETRY OF A MISSILE WITH VARYING ROLL RATE. Ch. H. Murphy and J. W. Bradley. US, BRL Rep. 1077, May, 1959. 35 pp. Study of the effect of a varying roll rate on the aerodynamic jump. In the case of roll produced by differentially canted controls, the rolling motion can be described by two parameters. The magnitude and range of jump is presented for the pertinent range of these parameters.

VARIATIONAL APPROACH TO THE RE-ENTRY OF A BALLISTIC MISSILE. I. Angelo Miele and C. R. Cavoti. Purdue U. Sch. Aero. Eng. Rep. A-59-1, Jan., 1959. 55 pp. 12 refs. Army-supported investigation of the re-entry of a ballistic missile endowed with a drag regulating device with the idea of minimizing the heat transferred from the boundary layer to the skin. Using the indirect methods of the calculus of variations it is shown that the totality of extremal arcs includes sub-arcs flown with spoilers fully retracted, with spoilers fully extended, and with spoilers in a continuously variable position. Two types of boundary value problems not involving time are investigated: (1) free time, free final Mach Number -- the extremal arc is flown with spoilers fully extended; (2) free time, fixed final Mach Number -- the extremal arc includes an initial sub-arc flown with spoilers fully extended, followed by a final sub-arc flown with spoilers fully retracted.

VARIATIONAL APPROACH TO THE RE-ENTRY OF A BALLISTIC MISSILE. II. Angelo Miele and C. R. Cavoti. Purdue U. Sch. Aero. Eng. Rep. A-59-3, May, 1959. 59 pp. Army-supported analysis of the re-entry of a ballistic missile equipped with a device regulating the drag in order to minimize the heat transferred from the boundary layer to the skin. Problems where a time constraint is imposed on the flight path are considered. It is shown that sub-arcs flown with a continuously variable ballistic factor are generally present in the extremal solution. The latter may include from two to five different sub-arcs depending upon the problem under consideration. Both exact and approximate methods are supplied in order to calculate extremal paths under different types of boundary conditions. Rigorous sufficiency proofs are developed by means of Green's theorem.

EFFECT OF DRAG MODULATION ON THE MAXIMUM DECELERATION ENCOUNTERED BY A RE-ENTERING BALLISTIC MISSILE. Angelo Miele and J. O. Cappellari, Jr. Purdue U. Sch. Aero. Eng. Rep. A-59-6, June, 1959. 41 pp. Army-supported investigation of the re-entry of a ballistic missile equipped with a drag control device. General solutions for the distributions of Mach Number and deceleration along the re-entry path are obtained on the basis of the assumption that the ballistic factor ξ is an arbitrarily prescribed function of the pressure ratio π (the ratio of atmospheric pressure at any altitude to atmospheric pressure at sea level). It is shown that, by decreasing the ballistic factor as the missile moves toward lower altitudes, the maximum deceleration can be reduced to a considerable extent with respect to that of a constant geometry missile.

VARIATIONAL APPROACH TO PROBLEMS OF HYPERVELOCITY FLIGHT - FINAL REPORT. Angelo Miele. Purdue U. Sch. Aero. Eng. Rep. A-59-7, June, 1959. 18 pp. 13 refs. Army-supported review of the results on: (a) the effect of drag modulation on the heat transferred from the boundary layer to the skin of a missile; determination of the programing of the ballistic factor yielding a minimum heat transfer; (b) effect of drag modulation on the maximum deceleration encountered by a re-entering ballistic missile; study of the relationship between deceleration and programing of the ballistic factor; and (c) analysis of the flight path of a hypervelocity glider boosted by rockets; study of the burning program and of the lift program maximizing the range of a hypervelocity vehicle.

ON A CLASS OF VARIATIONAL PROBLEMS IN ROCKET FLIGHT. G. Leitmann. J. Aero/Space Sci., Sept., 1959, pp. 586-591. Analysis considering the problem of determining the direction and magnitude of the bounded thrust of a single-stage rocket, traveling in vacuum and a constant gravitational field, in order to minimize a function of the initial and final values of rocket mass, position and velocity components, and time. The general nature of the extremal arc is derived from a consideration of necessary conditions for the existence of a minimum "pay off". Criteria are established for the identification of extremal subarcs and for their composition into the complete extremal arc. It is found that flight takes place either at maximum or minimum thrust and that, at most, three such subarcs can arise.

COLLISION TRAJECTORIES IN THE THREE-BODY PROBLEM. E. T. Benedikt. J. Astron. Sci., Summer, 1959, pp. 17-24, 30. Analysis covering the determination of the connection between the analytical regularity of the trajectory

of a missile moving under the action of two attracting masses and the collision between the missile and the center of one of the bodies. The basic results obtained by Levi-Civita are rederived in a manner following the formal methods of dynamics. Thus, it is possible to regularize collision trajectories and to obtain conditions which the position and velocity of the missile must satisfy in order for the trajectory of the missile to pass through the center of the body. Application of the foregoing developments to the case of circumlunar trajectories is made.

THREE-DIMENSIONAL LUNAR MISSION STUDIES. W. H. Michael, Jr., and R. H. Tolson. US, NASA Memo. 6-29-59L, June, 1959. 38 pp. Calculation of some three-dimensional lunar trajectories by integration of the equations of motion of the classical restricted three-body problem of celestial mechanics. The calculations have been used for the analysis of several aspects of lunar flight including requirements for achieving lunar impact and for establishing a close lunar satellite. It is concluded that the allowable errors in initial conditions for lunar missions are strongly dependent on the values of the initial injection velocity and the injection angle. There can be large differences in results obtained from two- and three-dimensional analyses. Some of the accuracy tolerances can be fairly well estimated by use of a two-body analysis. Satisfactory orbits for a relatively close lunar satellite can be obtained with accuracies in the initial conditions approximately equal to those required for lunar impact.

HETEROGENEOUS CONSTRUCTION FOR MISSILE FUSELAGES. A. T. Zahorski. USAF WADC TR 58-513 [AD 207270], Nov., 1958. 124 pp. 33 refs. Discussion of a preliminary design synthesis of a new type of heterogeneous fuselage structures, emphasizing their potential advantages over conventional semimonocoque structures. Included are the principles of heterogeneous construction, application to design of fuselages, selection of prototype, elastic connectors, and design recommendations. Burst, bending, and supersonic wind-tunnel tests on a full-size prototype fuselage are described.

GENERAL RESEARCH IN FLIGHT SCIENCES - FLIGHT DYNAMICS AND SPACE MECHANICS. I - "FREE" PITCH-YAW DYNAMIC RESPONSE OF A SPINNING BALLISTIC BODY IN A TIME-VARYING AERODYNAMIC ENVIRONMENT. J. S. Kanno. Lockheed Aircraft Missiles & Space Div., vol. IV, TR LMSD-48381, Jan., 1958-Jan., 1959. 13 pp. Evaluation of a linear differential equation pertinent to some flight-dynamic problems, including the prediction of vehicle dynamic response and the analysis of flight test data. Its variable coefficients are the aerodynamic static stability and the damping moments. For a statically stable ballistic configuration with small damping, the nutational and precessional displacements are oscillatory and are characterized by the waveform concepts of amplitude and frequency. The approximate solution of the equation of motion is resolved within the bounds of small aerodynamic damping, having a first-order effect on the envelope without influencing the epicyclic characteristics of the figure axis trajectory.

GENERAL RESEARCH IN FLIGHT SCIENCES - FLIGHT DYNAMICS AND SPACE MECHANICS. II - SELF-SUSTAINED EPICYCLIC PITCH-YAW OSCILLATIONS OF A SPINNING BALLISTIC BODY CHARACTERIZED BY THE VAN DER POL DAMPING FUNCTION. J. S. Kanno. Lockheed Aircraft Missiles & Space Div., vol. IV, TR LMSD-48381, Jan., 1958-Jan., 1959. 11 pp. Presentation of the results of an investigation on the limit cycle phenomenon of the blunt-nosed ballistic (re-entry) body. The solution of the equation of motion is derived by the approximate quasi-harmonic method of Kryloff and Bogoliuboff. The importance of the stable limit-cycle condition is stressed.

RELATIVISTIC TREATMENT OF AN OPTIMUM ROCKET PROPULSION SYSTEM UNDER CONSIDERATION OF NUCLEAR DATA. Trutz Foelsche. USAF MDC TN 59-8 [AD 214006], Apr., 1959. 9 pp. Description of an optimum propulsion system, including the limitation of the end velocity of a rocket using such a propulsion system by the low mass conversion factor of fuel. It is shown that for nuclear physical reasons an end velocity higher than 0.134c (c being the speed of light) cannot be attained by a rocket using a propulsion system with variable exhaust velocity, which maximizes the end velocity at given energy content and mass ratio.

GENERAL SOLUTION FOR OPTIMIZATION OF STAGING OF MULTISTAGED BOOST VEHICLES. C. H. Builder. ARS J., July, 1959, pp. 497-499. Presentation of a solution based upon weight-dependent criteria. Optimization is possible in terms of any criterion which can be expressed as proportional to stage or step weight, such as cost, volume, empty weight, propellant weight, as well as that of gross weight. The solution is applicable to a vehicle of any number of stages, including the air-breathing engine stage, having different performances and characteristics. Analytic procedures for the solution of multistage vehicles are outlined, and an example of the optimization of staging for minimum cost is presented.

CORRECTION OF EPOCH ERROR IN CIRCULAR ORBITS. II - CORRECTION BY NON-TANGENTIAL TRANSFER. L. J. Berman. MIT Dept. Aeron. & Astron. Rep. (AFOSR TN 59-62, Pt. 2) [AD 214637], Apr., 1959. 36 pp. Study of a vehicle in circular orbit which is transferred into a second orbit by an impulsive force. At some subsequent intersection of the two orbits, a sec-

ond impulse is applied to transfer it back to the original orbit. The maneuver is studied to determine what conditions affect the choice of the transfer orbit. In particular, the time taken for completion of the epoch change and the characteristic velocity required are studied. Finally, it is shown that the imposition of a restriction on the minimum perigee radius considerably modifies the choice and even makes some conditions impossible to satisfy.

WATER-LANDING CHARACTERISTICS OF A REENTRY CAPSULE. J. R. McGehee, M. E. Hathaway, and V. L. Vaughan, Jr. US, NASA Memo. 5-23-59L, June, 1959. 27 pp. Experimental and theoretical investigation to determine the water-landing characteristics of a conically shaped re-entry capsule having a segment of a sphere as the bottom. The peak accelerations along the roll axis experienced by this type of capsule were in the order of 40g for a contact attitude of 0° and a vertical flight path. For a contact attitude of 0° and a flight path of 65°, the peak accelerations were in the order of 50g. Changes in contact attitude in either the positive or negative direction from 0° attitude resulted in a considerable reduction in the peak accelerations. Accelerations measured along the pitch and yaw axes were relatively small at all test conditions. Excellent agreement was obtained among the peak accelerations of the model, full-scale, and rigid-body theoretical investigations.

PHYSICS

Geophysics

THEORETISCHE UNTERSUCHUNGEN DES CHEMISCHEN UND PHYSIKALISCHEN ZUSTANDES DER ATMOSPHÄRE ALS GRUNDLAGE FÜR EXPERIMENTELLE UNTERSUCHUNGEN IHRER MÖGLICHEN EINWIRKUNG AUF DIE MATERIALIEN VON FLUGKÖRPERN. U. Schmieschek. DVL Bericht No. 95, May, 1959. 38 pp. 36 refs. Westdeutscher Verlag, Köln & Opladen. In German. Theoretical investigation of the chemical and physical characteristics of the atmosphere based on data obtained by means of sounding rockets. The photochemical splitting processes and secondary reactions generated at high altitudes by solar radiation are studied. Special attention is given to the ozone formation as well as to the formation of free oxygen and nitrogen atoms. Also described are the conditions for test chambers and channels in studying the corrosive effect of the higher atmosphere on the metallic surfaces of missiles.

IZUCHENIE ZEMNOGO KORPUSKULIARNOGO IZLUCHENIIA I KOSMICHESKIKH LUCHEI PRI POLETE KOSMICHESKOI RAKETY. S. N. Vernov, A. E. Chudakov, P. V. Vakulov, and Iu. I. Logachev. AN SSSR Dokl., Mar. 21, 1959, pp. 304-307. In Russian. Investigation of the terrestrial corpuscular radiation and cosmic rays, covering interpretation of data obtained by a cosmic rocket for distances of 8,000 to 150,000 km. from the center of the earth. The instrumentation of the satellite is described, and the results are compared to the data obtained by the third artificial satellite. The spatial distribution of the high-intensity zone and the composition of the radiation in the external zone of high intensity are included.

POWER PLANTS

PROPULSION PAR PLASMA ACCELERE. L. Gérardin. Fusées, June, 1959, pp. 15-25. 16 refs. In French. Evaluation of the advantages of accelerated plasma propulsion in terms of its application to space vehicles. The survey of systems includes electrodynamic ion, thermodynamic plasma, and magnetodynamic plasma engines, as well as various energy sources. The basic operating principles, thrust, and certain design aspects of each system are discussed.

INVESTIGATION OF DIRECT CONVERSION DEVICES FOR APPLICATION TO ION PROPULSION. A. L. Huebner. North Am. Av. Rocketdyne Div. R-1463 (AFOSR TN 59-461) [AD 215266], May, 1959. 40 pp. 12 refs. Discussion of the applicability of photovoltaic cells to ion propulsion and analysis of their merit as a propulsion device of extremely high reliability. The theory of the cells is developed briefly, and the important parameters affecting their operation are studied, particularly with respect to conversion efficiency, operating temperature, and specific weight.

Jet & Turbine

HEAT TRANSFER PROCESSES IN GAS TURBINE COMBUSTION CHAMBERS. A. H. Lefebvre and M. V. Herbert. Gt. Brit., NGTE Memo. M.324, Feb., 1959. 41 pp. 13 refs. Simple analysis of the relevant heat transfer processes leading to a general equation for average flame-tube wall temperatures. This equation is applied to show the separate effects on flame-tube temperature of changes in the inlet variables of pressure, temperature, and air mass flow. The effect on metal temperatures of simultaneous changes in these three variables is also studied. Results indicate that flame-tube temperatures increase with increases in pressure, inlet temperature, and flame-tube size, and decrease in air mass flow. At constant engine rotational speed, flame-tube temperatures increase with increasing forward speed and decrease with increasing altitude.

UNTERSUCHUNGEN ÜBER DIE UMLENKUNG EINES FREIEN LUFTSTRAHLS MIT HILFE VON DRALL. Klaus Iserland. ETH Inst. für Aerodynamik, Mitteil. No. 25, 1958. 99 pp. In German. Investigation of the free air jet deflection including a survey of known systems. The study covers technical aspects of thrust reversal as compared to wheel brakes and brake parachutes;

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description of a system with spin, including the test apparatus; various experimental programs; free jet measurements; comparison of results; and experiments on thrust reversal with suction.

Rocket

VAPORIZATION RATE LIMITED COMBUSTION IN BIPROPELLANT ROCKET CHAMBERS. E. Mayer. (ARS 13th Annual Meeting, New York, Nov. 17-21, 1958.) ARS J., July, 1959, pp. 505-513. 16 refs. Analysis of a one-dimensional combustion-chamber model on the assumption that the vaporization of the liquid droplets is the rate controlling step in the combustion process. The dependence of the gas flow variables on position coordinate in the chamber is determined by assuming that the vaporized propellants are instantaneously mixed and reacted in stoichiometric ratio, and that the droplet motion is governed by full entrainment in the product gas flow. It is concluded that in the bipropellant system gas velocity distribution is determined primarily by the droplet spectrum and volatility of the more slowly vaporizing species, and that the temperature distribution is strongly dependent on the droplet size spectrum and volatility of the more rapidly vaporizing species.

DIMENSIONAMENTO DI UNA CARICA DI PROPELLENTE SOLIDO PER ENDOREATTORE DEL TIPO A STELLA INTERNA. Antonio Angeloni. Missili, Apr., 1959, pp. 23-35. In Italian. Study of the dimensioning of a solid propellant charge for rocket engines of the internal star type. Such aspects as the burnout, pressure, velocity, and combustion time are considered, and the cases of constant thrust and constant acceleration are presented as illustrative examples. Includes evaluation of geometrical and thermodynamic parameters involved in the selection of grain size and introduction of the assumption that the combustion surface advances parallel to itself, while the combustion velocity, normal to the surface, remains the same at all points.

RESEARCH, RESEARCH FACILITIES

Wind Tunnels

CALCULATION OF FLEXIBLE WALL SHAPES AND PREPARATION OF CONTROL TAPES FOR THE BEDFORD 8 ft. x 8 ft. WIND TUNNEL. Appendix I - DEVELOPMENT OF THE AERODYNAMIC EQUATIONS OF FLOW. K. V. Diprose. Appendix II - NUMERICAL METHODS. M. M. Barritt. Gt. Brit., RAE Rep. M.S. 54, Feb., 1959. 45 pp. 13 refs. Application of a digital computer to the aerodynamic design and automatic control of a large wind tunnel with flexible walls. The computational problem is threefold: first, calculation of the wall shapes for a set of "pivotal" operating speeds between Mach Numbers 1 and 2.8; second, computation of the necessary movements of the set of screw jacks which flex the walls; and finally, preparation of the set of digitally punched control tapes. A new mathematical approach was used for the first part in order to avoid singularities in the partial differential equations governing the flow in the convergent-divergent nozzle of the tunnel.

AN INVESTIGATION OF INTERFERENCE EFFECTS ON SIMILAR MODELS OF DIFFERENT SIZE IN VARIOUS TRANSONIC TUNNELS IN THE U.K. F. O'Hara, L. C. Squire, and A. B. Haines. Gt. Brit., RAE TN Aero. 2606; ARA Wind Tunnel Note 27, Feb., 1959. 82 pp. 18 refs. Presentation of test results made on similar swept-wing models in transonic tunnels of different types. Force measurement results at subsonic speeds in the RAE 3-ft.x 3-ft. slotted tunnel show only small interference effects for models of moderate blockage at low incidence; at higher incidences, the interference effect on lift becomes appreciably greater than estimated by theory and significant pitching moment occur, apparently due to wall interference on the wing flow field. Comparable but smaller effects are evident in the results from the ARA 9-ft.x 8-ft. perforated tunnel. At speeds just above Mach Number 1, the force fluctuates as speed is increased, because of wave reflection interference. The magnitude of the fluctuations diminishes as speed is further increased and this reduction is more marked in the perforated tunnel. Pressure measurements along the top of the body at zero incidence show delay in shock movements at higher subsonic speeds indicating a blockage effect in speed; the effect is larger in the perforated tunnel though smaller than predicted by theory.

ROTATING WING AIRCRAFT, HELICOPTERS

BERECHNUNGSMETHODEN UND KURVENBLÄTTER ZUR ERMITTLUNG DER FLUGLEISTUNGEN VON DREHFLÜGELFLUGZEUGEN. W. Just and H. Dathe. DSH Bericht No. 30, Jan., 1959. 120 pp. In German. Presentation of methods and graphs for calculating the performance of rotating wing aircraft in hovering, vertical, and horizontal flight. Curves are given for such parameters as rotor disc loading, rotational velocity, and parasite drag. For the case of hovering flight, methods of calculation based on both the jet theory and the airfoil theory are discussed.

STABILITÄT ELASTISCHER ROTORBLÄTTER MIT KONSTANTER MASSENBELEGUNG. H. Hain. DSH Bericht No. 39, Jan., 1959. 27 pp. In German. Development of a method to study the stability of elastic rotor blades with constant mass distribution. The effect of five structural and operating parameters is determined; the simplifying assumptions introduced into the calculation are stated; and the results are presented in graphical form.

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STRUCTURES

Beams & Columns

ANALYSIS OF A CANTILEVER BEAM DEVELOPING AN ISOPLASTIC RESPONSE UNDER IMPACT AT THE TIP. A. H. Hall and V. L. Saxon. Canada, NRC Aero. Rep. LR-237, May, 1959. 16 pp. Definition of a condition of isoplasticity for a beam as the development of plastic strains simultaneously at all points along the profile fibers. Two conditions must be satisfied simultaneously -- one on the profile shape, and one on the mass distribution. It appears that the second condition can only be approximately satisfied if there is relatively large mass concentration at the tip. Preliminary experiments using a massive striking force on a statically constant stress cantilever indicate that a condition of isoplasticity may be approached.

CREEP BEHAVIOR OF COLUMNS. S. A. Patel and B. Venkatraman. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 422 (AFOSR TN 59-530) [AD 216537], May, 1959. 84 pp. 42 refs. Investigation of the creep behavior of pin-ended viscous and viscoelastic columns. The analyses are carried out on the basis of an assumed I-section and a term is introduced to account for plastic deformations. The transient creep law is used to study the short-time buckling, and the validity of the assumptions introduced into the analysis is examined.

Cylinders & Shells

CREEP BUCKLING OF CYLINDRICAL SHELLS SUBJECTED TO UNIFORM AXIAL COMPRESSION. F. W. French and S. A. Patel. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 489 (AFOSR TN 59-538) [AD 215555], May, 1959. 18 pp. Investigation of the axially symmetric creep buckling of a circular cylindrical shell using a sandwich shell analogy and a biaxial creep law. Two simultaneous, nonlinear equations are found to govern the stress distribution in and the displacement of the cylinder. One specific example is given, and the results are presented in the form of curves.

DETERMINATION OF STATIC STRENGTH AND CREEP BUCKLING OF UNSTIFFENED CIRCULAR CYLINDERS SUBJECTED TO BENDING AT ELEVATED TEMPERATURES. E. E. Mathauser and Avraham Berkovits. US, NASA Memo. 6-14-59L, June, 1959. 18 pp. Development of a method based on a semiempirical procedure applicable to cylinders that are loaded into the inelastic stress range prior to buckling and fail in a local mode. The predicted bending moments associated with static strength and creep buckling are compared with experimental data obtained from tests at 500° F. on 5052-0 aluminum-alloy cylinders with radius-thickness ratios ranging from 125 to 250. The bending strength of the cylinders is determined on the basis of an existing local buckling stress relationship and the compressive stress-strain curve for the material. Creep buckling is determined with the use of isochronous stress-strain curves obtained from compressive creep data.

THERMAL BUCKLING OF CIRCULAR CYLINDRICAL AND CONICAL THIN-WALLED SHELLS. David Abir, N. J. Hoff, S. V. Nardo, F. V. Pohle, William Vafakos, and Koon-Sang Wan. USAF WADC TR 58-104 [AD 151068], Apr., 1958. 161 pp. 18 refs. Experimental and theoretical investigation of temperature distribution and thermal stresses in thin-walled circular cylindrical and conical shells. Both reinforced and unreinforced types are considered. It is concluded for the thin circular cylindrical shell that the critical value of the axial compressive stress due to variable circumferential temperatures does not differ from the critical stress of a cylinder loaded in uniform axial compression, provided the variation of the thermal stress over a one-half wavelength is not large. The reinforced conical shells were heated uniformly and their buckling time was found to be higher than that predicted by theory. The unreinforced conical shells, heated axisymmetrically with a variation of the heat input only in the axial direction, melted and showed no signs of buckling.

ON TORSION OF THIN CYLINDRICAL SHELLS. E. Reissner. J. Mech. & Phys. Solids, June, 1959, pp. 157-162. ONR-supported application of the theory on thin, elastic, cylindrical shells to the problem of St. Venant torsion. General explicit results for nonhomogeneous shells are obtained, including as special case Bredt's formulas for closed tubes and known results for tubes slit along a generator. It is shown that the assumptions of Love's first approximation shell theory are not applicable to the problem of nonhomogeneous and longitudinally slit tubes.

THE LOAD CARRYING CAPACITIES OF CYLINDRICAL SHELLS SUBJECTED TO A RING OF FORCE. G. Eason. J. Mech. & Phys. Solids, June, 1959, pp. 169-181. Determination of the stress fields and associated velocity fields obtained under conditions of axial symmetry for circular cylindrical shells of rigid-plastic material satisfying the Tresca yield condition. The value of collapse force is found for all values of the shell length, and five possible types of deformation are indicated.

Elasticity & Plasticity

THREE SHEAR THEORY OF PLASTICITY. Fujio Nakanishi and Yasuo Sato. JSME Bul., May, 1959, pp. 257-264. Development of a theory of plasticity and discussion of its application

to the determination of stress relation between plastic pure shear and plastic tension. The hysteresis loops and the anisotropy due to plastic deformation are investigated, and the relation between the yield point of mild steel and the plastic deformation setting in beyond that point is discussed. Experimental and theoretical results are found to be in good agreement.

Fatigue

FATIGUE CHARACTERISTICS OF A RIVETED 24S-T ALUMINIUM ALLOY WING. IV - ANALYSIS OF RESULTS. D. G. Ford and A. O. Payne. Australia, ARL Rep. SM. 263, Oct., 1958. 77 pp. 21 refs. Evaluation of results obtained from fatigue tests on ninety P-51D Mustang wings. Includes development of a method for relating the fatigue strength of the structure to that of two critical components in which fatigue failure occurs. Also presented are data on such aspects as: types of fatigue failure, frequency distribution of fatigue life, fatigue strength of notched material, and the effect of preloading on fatigue characteristics.

A STUDY OF CREEP, CREEP-FATIGUE, AND THERMAL-STRESS-FATIGUE IN AIRFRAMES SUBJECT TO AERODYNAMIC HEATING. Joseph Padlog and Arthur Schnitt. USAF WADC TR 58-294 [AD 211651], July, 1958. 222 pp. 202 refs. Examination of methods for predicting creeps deformation, creep-rupture, creep-fatigue, and creep-buckling under intermittent or cyclic temperature and load conditions, using isothermal constant-load or cyclic load data. A procedure is formulated for the determination of optimum design curves for multiweb structures when creep-buckling of the compression cover is the predominant mode of failure. Optimum curves are presented for two aluminum alloys and a variety of assumed flight plans, and for the tension cover and the pertinent modes of failure. A tentative elevated-temperature design criterion is suggested, and optimum design envelopes are obtained, from which the criticalness of each mode of failure may be ascertained. The order of magnitude of permissible creep deformations for wings is determined and the various mechanisms leading to thermal-stress-fatigue are discussed; a criterion for the prediction of this phenomenon is also presented.

Plates

USTALONE NAPRĘŻENIA CIEPLNE W PŁYTACH. Witold Nowacki. Rozprawy Inżynierskie, No. 1, 1959, pp. 4-24. In Polish, with summaries in English and Russian. Presentation of a method for determining stresses in a plate of moderate thickness in a temperature field, using Green's function of the differential equation of the problem. For a number of simple cases such as that of infinite plate, plate strip, plate wedge, etc., bending moments and torques are determined for a continuous and discontinuous temperature field. Finally, thermal stresses are discussed for a few cases of plates resting on an elastic foundation.

THEORETICAL AND EXPERIMENTAL STUDIES OF THE STRESSES AND STRAINS AROUND CUTOUTS IN LOADED, UNEVENLY HEATED PLATES. Appendix A - DETAIL DEVELOPMENT OF ANALYTICAL METHOD. Appendix B - THE TEST FACILITY. Appendix C - ELEVATED-TEMPERATURE STRAIN-SENSITIVE COATINGS. Appendix D - TEST DATA. P. C. Huang and C. J. Van Der Maas. USAF WADC TR 59-2 [AD 212565], Mar., 1959. 162 pp. Presentation of a method for calculating the stresses and strains in unevenly heated flat plates with discontinuities. The method of analysis is limited to elastic loads in the plane of the plate and to temperature and strain distributions which are two-dimensional. Several experiments using 2024-T4 bare aluminum plates with square cutouts are reported in detail. It is concluded that the analytical method has been verified by the experimental data.

Sandwich Construction

STABILITY OF FLAT, SIMPLY SUPPORTED, CORRUGATED CORE SANDWICH PLATES UNDER COMBINED LONGITUDINAL COMPRESSION AND BENDING, TRANSVERSE COMPRESSION AND BENDING, AND SHEAR. L. A. Harris and R. R. Auelmann. IAS Natl. Summer Meeting, Los Angeles, June 16-19, 1959, Paper 59-87. 15 pp. Members, $0.50; nonmembers, $1.00. Derivation of buckling curves by means of the Rayleigh-Ritz energy method in which the deflection surface due to shear is assumed to be of the same form as the deflection surface due to bending and twisting. The solution of the eigenvalue problem for the buckling coefficients was performed by a matrix iteration procedure on an IBM 704 computer. In defining the sandwich, the core shear modulus in the direction of the corrugation is assumed to be infinite, whereas the corresponding modulus in the crosswise direction is finite. The skins are assumed to be isotropic. The flexural stiffness of the core in the longitudinal direction is taken into account. The effects on the buckling coefficient of the core longitudinal stiffness and of Poisson's ratio of the skins are also investigated.

FLEXURAL VIBRATIONS OF ELASTIC SANDWICH PLATES. Yi-Yuan Yu. Polytech. Inst. Bklyn., Dept. Mech. Eng. TN 3 (AFOSR TN 59-188) [AD 211219], Mar., 1959. 29 pp. Analysis of flexural vibrations by two different methods: (1) a flexural theory for sandwich plates, developed previously, which takes into account the effects of rotatory inertia and shear in the core and faces of the sandwich; and (2) an exact elasticity theory. For ordinary sandwich plates that have relatively thin but heavy and rigid faces, the frequency equations may be reduced, and a numerical example is given. The results of the

sandwich-plate theory show excellent agreement with those of the elasticity theory, and the former are shown to be applicable also to simply supported finite plates. It is finally concluded that the effects of rotatory inertia and shear play an even more important role in vibration studies of sandwich plates than in homogeneous plates.

Thermal Stress

ENERGY METHODS FOR THE ANALYSIS OF TEMPERATURE DISTRIBUTIONS AND THERMAL STRESSES IN STRUCTURES. G. Herrmann. Columbia U. Dept. Civ. Eng. & Eng. Mech. Inst. Flight Struc. TN 2 (AFOSR TN 59-327) [AD 213675], May, 1959. 12 pp. Presentation of some energy theorems of structural analysis in a generalized form for the case when a part of the stresses is due to thermal effects. The three energy methods discussed represent extensions of Green's principle for displacements, Castigliano's principle for stresses, and Reissner's generalized principle for displacements and stresses. These methods assume that the temperature distribution is known. It is shown further that the temperature distribution in the structure itself may be determined by the use of analogous energy theorems, which can be established for both steady-state and transient conditions.

TRANSIENT THERMAL STRESSES IN AN ELASTIC HALF-SPACE. C. H. J. Johnson. Australia, ARL Rep. Me. 89, Nov., 1958. 15 pp. Derivation of expressions for the transient thermal stress distribution within an elastic half-space. Three cases of temperature boundary conditions are considered: (a) uniform constant temperature on the boundary plane; (b) uniform constant heat flux on the boundary plane; and (c) radiation to the boundary plane from a medium at constant temperature. In all cases it is assumed that the temperature of the medium is zero and the medium is initially unstrained.

O NEKOTORYKH PROSTRANSTVENNYKH ZADACHAKH TERMOUPRUGOSTI. Vitol'd Novatskii. Prikl. Mat. i Mekh., May-June, 1959, pp. 456-467. In Russian. Study of thermal stresses due to the effect of nonstationary heat sources arbitrarily distributed in elastic and viscoelastic media. The derivation of Green's functions for stresses produced by instantaneous concentrated heat sources is analyzed, and the state of stress in perfectly elastic and viscoelastic bodies is studied.

THERMAL STRESS PROPAGATION IN VISCO-ELASTIC BODIES. I. W. Nowacki. Acad. Pol. Sci. Bul., Tech. Sci. Ser., No. 4, 1959, pp. 257-263. Presentation of an analysis assuming that: (a) an instantaneous source of heat acting in an infinite visco-elastic space results in a temperature and stress field; (b) the visco-elastic medium, of linear characteristic, is isotropic and homogeneous; and (c) the deformations are small and the physical constants are independent of temperature. A displacement equation is derived on the basis of Biot and Berry's relations and the potential of thermoelastic strain is introduced. After application of the inverse Laplace transformation, the relation between the state of stress and that of strain is determined.

A METHOD FOR SOLVING LINEAR THERMO-ELASTIC PROBLEMS. R. J. Knops. J. Mech. & Phys. Solids, June, 1959, pp. 182-192. 10 refs. Development of a method depending upon the thermoelastic equations being identical in form to the equations obtained by subtracting those of the isothermal elastic state for two arbitrary values of Poisson's ratio. The identity is used to formulate the relation between two problems, and the procedure is illustrated on the case of the half-space and a space bounded by two infinite parallel planes. A sketch is given of the procedure to be adopted and a new solution is presented for the thick plate with stress-free boundaries.

CREEP BUCKLING OF PLANE FRAMEWORKS. Jan Hult. KTH Trans. 136, 1959. 30 pp. 11 refs. Study of (a) the problem of linear viscoelastic creep buckling in structures with members of arbitrary cross sections in analogy to elastic buckling theory and (b) that of nonlinear creep buckling in structures with idealized H cross sections where all deformation is concentrated in creep hinges. A mechanical model is used to study the second case.

Wings

ANALYSIS OF LOW-ASPECT-RATIO AIRCRAFT STRUCTURES. Ch. H. Samson, Jr., and H. W. Bergmann. IAS Natl. Summer Meeting, Los Angeles, June 16-19, 1959, Paper 59-88. Members, $0.50; nonmembers, $1.00. 27 pp. 14 refs. Presentation of two methods providing reasonable values for deformations and stresses of complex built-up low-aspect-ratio aircraft structures. The same structure, idealized as a network of flexural members with interconnected torsion boxes, is used in both cases for analytical purposes. The first method, based upon the principle of consistent distortion, considers the entire assemblage of structural elements and requires the inversion of a single structural matrix characterizing the complete structure. The second method, which utilizes the concept of transfer matrices, deals with segments of the structure and avoids the necessity of inverting high-order matrices. Comparisons of theoretical results by both methods with experimental data and electric analog solutions are favorable.

THERMODYNAMICS

Combustion

THE EFFECT OF PRESSURE ON THE BURNING VELOCITY OF VARIOUS GAS MIXTURES

(MEASURED BY THE SOAP BUBBLE METHOD). W. A. Strauss and Rudolph Edse. USAF WADC TR 58-464 [AD 211031], Dec., 1958. 38 pp. 10 refs. Description of experiments conducted with various gas mixtures at room temperature over a pressure range between 1 and 90 atm. by means of the constant-pressure bomb method. The results show that mixtures whose adiabatic flame temperatures increase with pressure also have burning velocities which increase with pressure. Conversely, mixtures whose flame temperatures increase little or not at all with increasing pressure have burning velocities which decrease with increasing pressure. It is found that the effect of pressure on the burning velocities of premixed gas mixtures can be explained by the effects of pressure on the rate of diffusion of active radicals, on the rate of heat transfer from burned to unburned gas, and, in cases where a chemical reaction is the rate determining process, by the effect of pressure on this chemical reaction. The rate at which the burning velocities decrease or increase depends on the particular system and its mixture ratio.

CORRELATION AND PREDICTION OF FLAME PROPERTIES WITH SPECIAL REFERENCE TO LIQUID HYDRAZINE. Melvin Gerstein. (ARS 13th Annual Meeting, New York, Nov. 17-21, 1958.) ARS J., July, 1959, pp. 514-519. Survey of available data and discussion of the application of existing correlations to the liquid hydrazine decomposition flame, covering such aspects as flame velocity, quenching distance, and the relation between flame velocity and quenching distance. It is shown that this type of flame, using a propellant with relatively simple flame kinetics which can support a flame when introduced either as a liquid or a gas, may be used to relate gas phase combustion studies and combustion of condensed phases, such as liquid and solid monopropellants.

THE STABILITY OF PROPELLANTS AND THE THEORY OF THERMAL IGNITION. Irvin Glassman. (4th Monopropellant Symposium, New York, May 5, 6, 1959.) Princeton U. Dept. Aero. Eng. Lab. Rep. 460 (AFOSR TN 59-586) [AD 217185], May, 1959. 19 pp. 12 refs. Description of the concept of stability by considering the fundamentals of the stability process in the light of thermal ignition theory. The limiting case of purely conductive heat transfer which takes place at small values of the Grashof criterion is considered, and the parameters describing the ignition criteria are derived from the heat conductance equation developed earlier. In the stationary theory only the temperature distribution throughout the reactant is considered and its change with time is not taken into account. In the nonstationary theory, the spatial distribution is not taken into consideration, but a mean temperature of the reactant or reactants, assumed to be equal at all points in the substance, is introduced and its dependence on time is examined.

Heat Transfer

HEAT TRANSFER IN THE RAREFIED GASES. I, II. Tetsuo Fujimoto and Kichiro Takao. JSME Bul., May, 1959, pp. 197-209. 10 refs. Derivation of a formula, based on Maxwell-Boltzmann's equation, for solving the steady, one-dimensional heat transfer between two parallel plates in a rarefied gas as a function of the distance from the wall. The simplifying assumptions introduced into the solution of the basic equation are stated, the six constants involved in the temperature-distribution formula are determined, and a comparison is made between theory and experiment.

VTOL & STOL

WIND TUNNEL TESTS OF SEVERAL DUCTED PROPELLERS IN NON-AXIAL FLOW. W. J. Gill. Hiller Aircraft Adv. Res. Div. Rep. ARD-224, Apr. 20, 1959. 386 pp. 10 refs. Navy-sponsored measurements of total aerodynamic forces and moments, the forces and moments acting on the duct itself, and the power supplied to the propellers. The models were tested at advance ratios of 0, 0.05, 0.10, and 0.15 with the duct axis tilted through a range of angles between 0° and 90°. Detailed velocity surveys were conducted in the slipstream, and vanes mounted in the slipstream were tested. Four ducts were tested in combination with three different sets of contrarotating, adjustable-pitch propellers. Three of the ducts had airfoil profiles (one with an exit diffuser), and the fourth consisted of a circular cylinder with a bell-mouth inlet formed by a lemniscate curve. The data are presented in the form of coefficients based on propeller tip speed, duct area, and propeller radius -- except for the duct alone (ring wing) data, for which the coefficients are based on tunnel air speed. In addition, slipstream flow survey data are presented in tabular form.

A POWER PLANT MAN'S LOOK AT THE GROUND EFFECT MACHINE. R. W. Pinnes. (US, NAVAER Rep. DR-1958, Apr., 1959.) AHS J., July, 1959, pp. 3-25. Analysis of the augmentation ratio due to ground effect that has been considered as approaching infinity as the height-to-diameter ratio approaches zero. It is demonstrated that such high augmentation ratios will not be obtained, and that they increase only up to a certain point. Beyond this point, the augmentation ratio actually decreases if the height-to-diameter ratio continues to be reduced to zero. These conclusions are based on a detailed flow analysis of the annular jet, considering the flow variations across the jet thickness. The concept of a fan augmentation ratio is developed, and it is shown that the optimum design (maximum lift force per installed horsepower) is actually a compromise between ground effect augmentation ratio and fan augmentation ratio. This is illustrated by means of a specific example.

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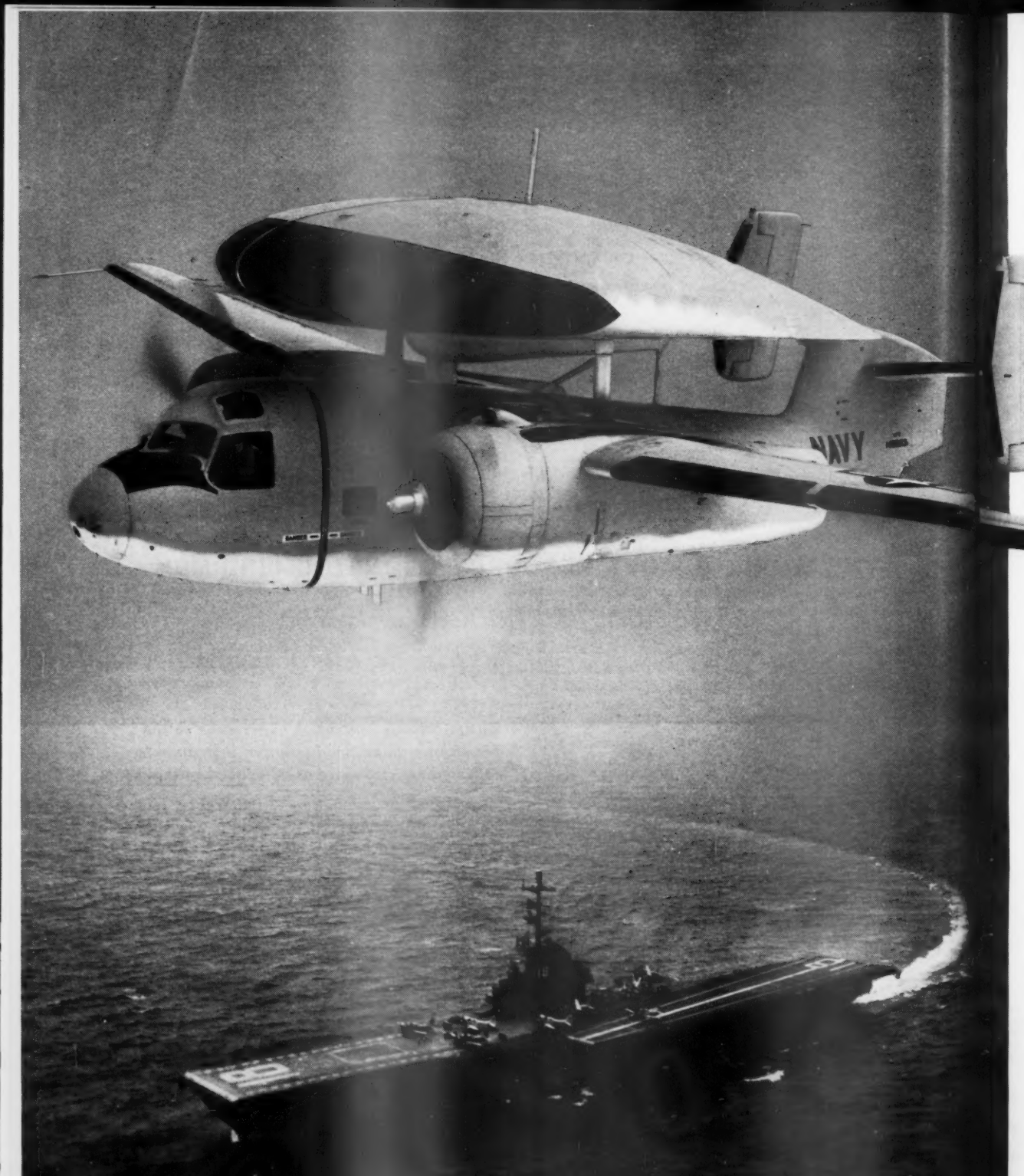

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Electronics Engineers, for career opportunities at Grumman Aircraft, see page 129.

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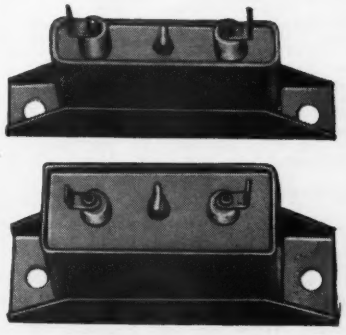

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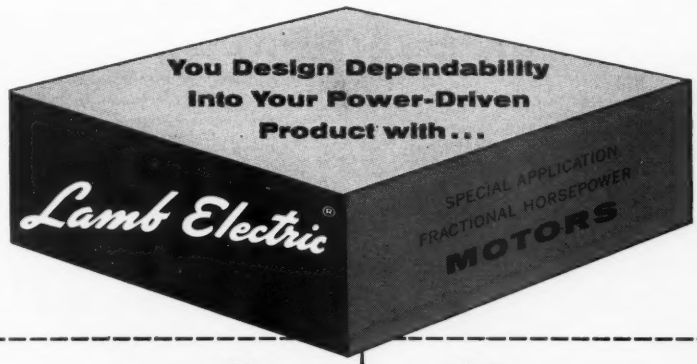

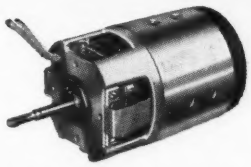

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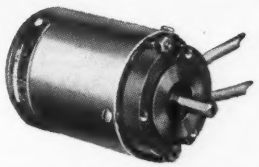

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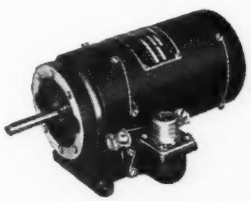

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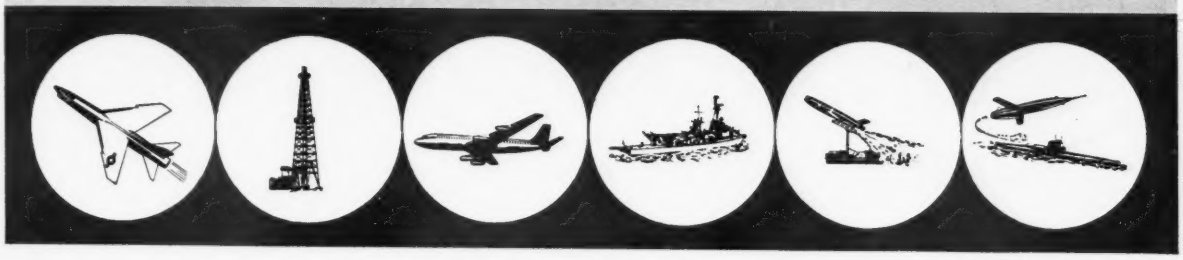

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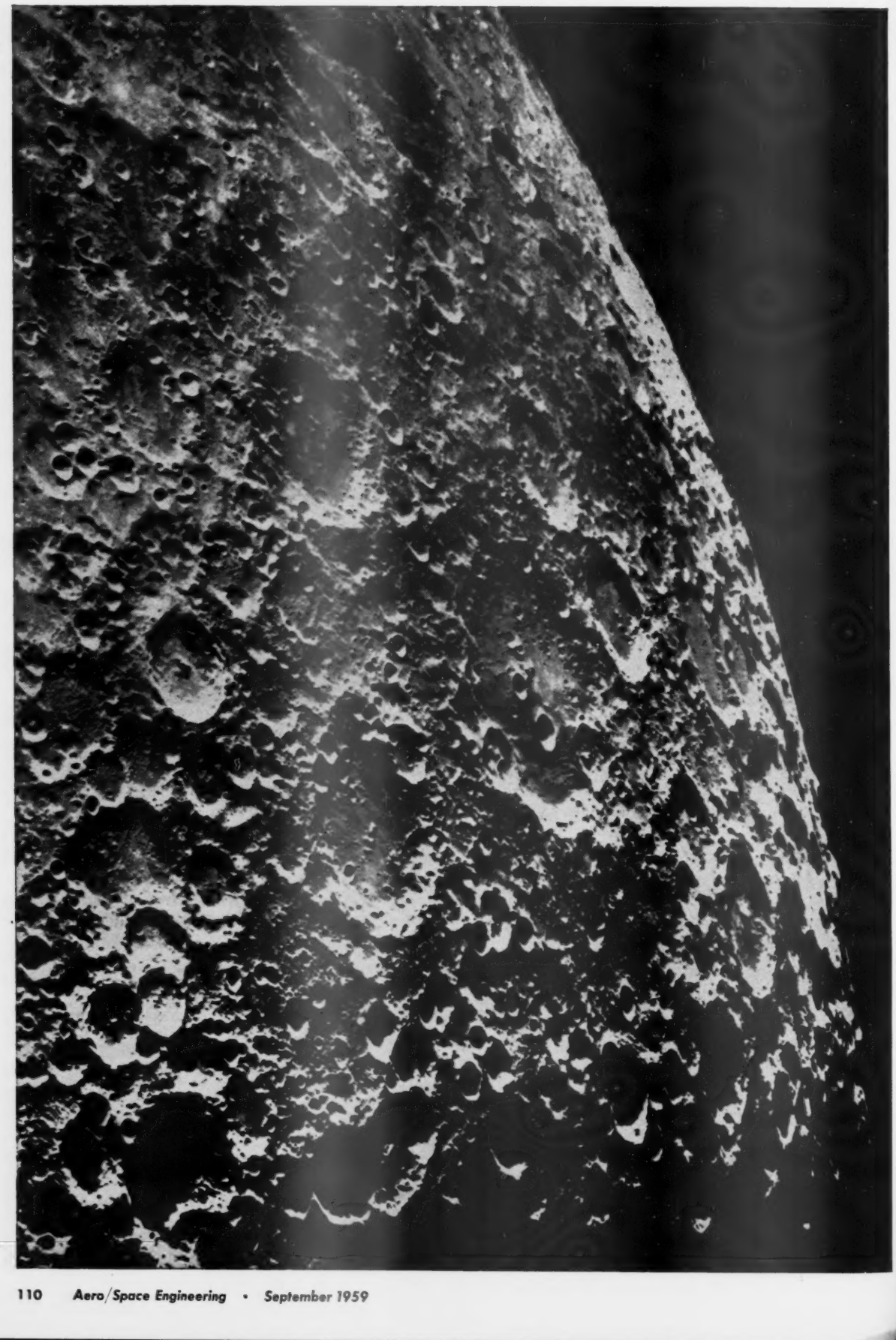

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Artificial Modification of the Earth's Radiation Belt. S. F. Singer. (*AAS 5th Annual Meeting, Wash., Dec., 1958.*) *J. Astron. Sci.*, Spring, 1959, pp. 1–10. 30 refs. AFOSR-supported discussion of a project to modify the radiation belt by artificial injection of particles using a small electron accelerator carried in a satellite. Such a modification would be a means for investigating upper atmosphere densities and the trapping properties of the earth's magnetic field.

Density and Temperature of the Upper Atmosphere. Robert Jastrow. *Astronautics*, July, 1959, pp. 24, 25, 108, 109. Analysis of IGY rocket and satellite data for temperature and density determination showing the strong latitude dependence of density.

The Sun and the Upper Atmosphere. Herbert Friedman. *Astronautics*, July, 1959, pp. 20–22, 55, 56. Discussion covering solar spectrum data obtained through rocket astronomy and the role played by solar radiations in the earth's atmosphere and in interplanetary space.

Energy Spectra and Nuclear Interactions of Cosmic-Ray Particles. N. M. Kocharian, G. S. Saakian, and Z. A. Kirakosian. (*Zhurnal Teoret. i Exper. Fiz.*, Dec., 1958, pp. 1,335–1,349.) *Sov. Phys. - JETP*, June, 1959, pp. 933–942. 23 refs. Translation.

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On Coordinate Conditions in Einstein's Gravitation Theory. I. G. Fikhtengol'ts. (*Zhurnal Teoret. i Exper. Fiz.*, Dec., 1958, pp. 1,457–1,465.) *Sov. Phys. - JETP*, June, 1959, pp. 1,108–1,023. Translation. Derivation of relations connected with the covariance of field equations under transformation of variables, and establishment of the relation between coordinate conditions and invariance of the field Lagrangian. The geometrical and physical properties of the coordinate systems corresponding to the coordinate conditions derived are considered.

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Positive Ions in the Ionosphere. J. C. Holmes and Ch. Y. Johnson. *Astronautics*, July, 1959, pp. 30, 31, 102, 104, 105. Description of the rocket instrumentation for measuring the upper atmosphere's ambient neutral gas, and positive- and negative-ion compositions. Results are presented.

Approach to the Ionosphere. W. W. Bening. *Astronautics*, July, 1959, pp. 26, 27, 116, 117. Discussion of past and present techniques for ionospheric studies with their limitations and possibilities.

Electrically Charged Bodies Moving in the Earth's Magnetic Field. W. W. Fain and B. J. Greer. *ARS J.*, June, 1959, pp. 451–453. Presentation of two-dimensional equations to determine the effect on the path of electrically charged bodies moving in the earth's magnetic and gravitational fields.

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Tochechnyi Istochnik Svetovogo Izlucheniia v Rasseivaiushchei Srede. L. A. Galin. *Prikl. Mat. i Mekh.*, Mar.-Apr., 1959, pp. 299–304. In Russian. Calculation of the distribution of light waves radiated by a point source in a diffusion medium, under the assumption of an isotropic diffusion.

The Inverse Scattering Problem in Geometrical Optics and the Design of Reflectors. J. B. Keller. *IRE Trans., AP Ser.*, Apr., 1959, pp. 146–149. USAF-supported study of methods to find the shape of a reflector which produces a prescribed scattered wave. Plane, cylindrical, and spherical incident waves are considered. The problem is solved by means of explicit formulas for cylindrical and for rotationally symmetric objects.

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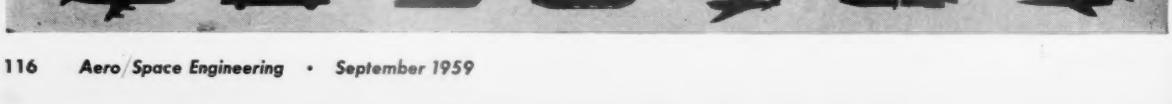

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Secondary Power in Advanced Flight Vehicles. Kelso Jones. *Aero/Space Engrg.*, Aug., 1959, pp. 54–57, 63. Analysis of the types of vehicles and the secondary power required for space exploration, and discussion of some of the objectives and problems in the field.

Symbiosis Shows the Way to Supersonic Success. *Aeronautics*, June, 1959, pp. 42–44. Historical survey covering the development of the Griffon and the turbo-ramjet power plant, as well as discussion of their characteristics.

Plasma Engine Delivers Nearly 2-lbs. Hal Gettings. *Missiles & Rockets*, June 8, 1959, pp. 34–36. Description of a magnetic pinch engine that produces a peak thrust of more than 4,000 lbs. with a specific impulse of over 1,700 sec.

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Why Free Turbines? D. P. Edkins. *Aero/Space Engrg.*, Aug., 1959, pp. 58–63. Brief summary of the characteristics of the helicopter rotor and the propeller as they affect the engine, and examination of the solid-spool,twin-spool, and free turbine turboprops. The inherent advantages of the free-turbine type engine with variable compressor stators are shown.

Turbojet Lift Engine Design for VTOL Transports. M. J. Saari. (*IAS-CAI Joint Meeting, Ottawa, Oct. 7, 8, 1958, Preprint 853.*) *Can. Aero. J.*, June, 1959, pp. 15–223.

Computer Application to Fuel System Design and Development. J. M. Tusiewicz. (*CAI Annual Gen. Meeting, Toronto, May 27, 1958.*) *Can. Aero J.*, June, 1959, pp. 224–232. Outline of the problem of turbojet engine control and discussion of possible solutions. The dynamics of the basic element of a hydraulic control system are examined, the turbojet engine dynamics are studied, and different levels of engine simulation are discussed.

Which Starter Will You Use? *SAE J.*, June, 1959, pp. 78–80. Discussion of basic components and characteristics of serveral types of starter systems for jet engines.

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What Makes the Tu-104 so Hot? R. A. Cole. *Aircraft & Missiles Mfg.*, July, 1959, pp. 48, 49. Brief discussion of the development of a special exhaust nozzle, the Vulis nozzle, which adds heat to the turbine exhaust. Thrust increases from 18 to 22 per cent are obtained.

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Suppression of Combustion Instability in the Plungerjet Rocket Engine. Herbert Shieber. *ARS J.*, June, 1959, pp. 446, 447.

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Packaged Propulsion. Kenneth Gatland. *The Aeroplane & Astronautics*, June 12, 1959, pp. 679–681. Description of the two-stage, solid propellant Polaris system and discussion of the thrust determination.

Storable Liquid Propellants Look Good for Drone Rockets. II. R. P. Reul. *Space Aeronautics*, July, 1959, pp. 75, 76, 78, 81. Presentation of basic design criteria for storable liquid propellant engine systems. Information is given on thrust chambers, valves and regulators, and propellants for optimum system application.

Dimensionnement Optimum de Tuyères de Propulseurs-Fusées. E. le Grivès and P. Larue. *La Recherche Aéronautique*, Mar.-Apr., 1959, pp. 9–14. In French. Analysis covering the optimum size of rocket nozzles in terms of thrust efficiency at high altitudes, and derivation of compromise values for various ranges of the relevant parameters.

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Thrust Alignment in Rockets. *Aircraft & Missiles Mfg.*, July, 1959, pp. 12–14. Description of techniques used by Rocketdyne to match the centerline of the thrust chamber with a line perpendicular to the plane of engine mounts.

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Der deutsche Nachbau der Noratlas 2501. II—Bau der Aussenflügel und der Leitwerke bei der Siebelwerke-ATG GmbH, Donauwörth. E. Stang. **III—Die Herstellung des Flügelmittelstückes, der Leitwerkträger, die Aufrüstung des Wechseltriebwerkes und die Überholung des Flugzeuges bei der Weser Flugzeugbau GmbH, Bremen.** A. Niehus. *Flugwelt*, Mar; May, 1959, pp. 94–98; 173—176. In German. Further survey covering the production of the Noratlas 2501, including the equipment used for wing and tail assembly, rigging of reciprocating engines, and overhaul of the aircraft.

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Optical Form-Grinding; Equipment for the Accurate Control of Ground Profiles. *Aircraft Prod.*, July, 1959, pp. 246–250.

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Heat-Extractive Brazed Bimetals Show Promise for Missile and Industrial Applications. R. C. Bertossa and Steven Rau. (*AWS 40th Annual Meeting, Chicago, Apr. 6–10, 1959.*) *Welding J. Res. Suppl.*, July, 1959, pp. 273-s–281-s. Results of a research program showing the feasibility of applying vacuum-brazing techniques to the protection of refractory metals under short-term exposures to temperatures up to and exceeding 3,600°F.

New Developments in the Welding of Aluminum. R. L. Hackman. (*AWS 40th Annual Meeting, Chicago, Apr. 6–10, 1959.*) *Welding J.*, July, 1959, pp. 676–684. Discussion of (a) the inert-gas consumable-electrode process as applied to the welding of very thin or thick material and (b) the tungsten-arc processes for spot welding.

Certain Structural Properties of Ultrasonic Welds in Aluminum Alloys. J. B. Jones and W. C. Potthoff. (*AWS 40th Annual Meeting, Chicago, Apr. 6–10, 1959.*) *Welding J. Res. Suppl.*, July, 1959, pp. 282-s–288-s. 10 refs. Test results indicating that ultrasonic welds have higher shear strengths than fusion-type welds in aluminum alloy up to 0.071-in. thick and require less critical sheet-surface preparation.

Kinetika Protsessa Plavleniia i Perenosa Elektrodnogo Metalla pri Dugovoi Svarke. A. A. Erokhin and V. A. Petrunichev. *AN SSSR Otd. Tekh. Nauk Izv. Metall. i Toplivo*, Mar.-Apr., 1959, pp. 70–77. In Russian. Results of experiments using high-speed photography to study the kinetics of the melting and metal transfer process in arc welding.

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Practical Statistical Quality Control in the Airframe Industry. III. J. Y. McClure. *Ind. Quality Control*, June, 1959, pp. 5–9. Discussion of quality control in assembly, pre-flight, and final inspection. Quality assurance reports for supervision and management are also discussed.

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A Wind-Tunnel Investigation of the Aerodynamic Characteristics of a Full-Scale Supersonic-Type Three-Blade Propeller at Mach Numbers to 0.96. A. J. Evans and George Liner. *U.S., NACA Rep. 1375*, 1958. 42 pp. Supt. of Doc., Wash., $0.25.

Flight Performance of a Transonic Turbine-Driven Propeller Designed for Minimum Noise. T. C. O'Bryan and J. B. Hammack. *U.S., NASA Memo. 4-19-59L*, May, 1959. 22 pp. Flight investigation of the performance of an advance-ratio-4.0 propeller designed for a Mach Number of 0.82 showing an efficiency of 68 per cent. A comparable propeller designed for optimum advance ratio (≈ 3) would have an efficiency as much as 15 per cent higher.

Research, Research Facilities

Problems of Ground Simulation of Long-Range Space Flight Environmental Conditions. T. C. Helvey. (*Internatl. Astron. Fed. Congr., Amsterdam, Aug. 25–30, 1958.*) *IRE Trans., SET Ser.*, June, 1959, pp. 57–60. Discussion of the simulation of multiple stresses and low-frequency, high-amplitude vibrations for structures or components; a chamber for simulating meteoric environment; a human oscillator; and other equipment for space simulation.

Full-Scale Propulsion Testing in Wind Tunnels. R. W. Hensel and H. K. Matt. *USAF AEDC TR 59-9 [AD 214888]*, May, 1959. 78 pp. 40 refs. Review of the development of full-scale propulsion testing, covering the range from low subsonic speeds at close to sea level conditions to high supersonic speeds at altitudes of over 100,000 ft.

The Large High Pressure Arc Plasma Generator: A Facility for Simulating Missile and Satellite Re-Entry. P. H. Rose, W. E. Powers, and D. Hritzay. *Avco Everett Res. Lab. RR 56*, June, 1959. 30 pp. 12 refs. Description of an arc plasma generator and its application to hypersonic and supersonic wind tunnels as a source of high-pressure, high-enthalpy air.

Ground-Testing the Ramjet. Philip Geddes. *Aircraft & Missiles Mfg.*, July, 1959, pp. 44–47. Description of engine tests using a blowdown air supply and jet engines as a heat source for the air.

High Power Pulse Steepening by Means of Exploding Wires. G. S. Janes and H. Koritz. *Avco Res. Lab. RR 50*, Apr., 1959. 19 pp. Description of a circuit technique which reduces the rise times of high power pulses by means of exploding wires.

Un Nouveau Laboratoire d'Essais à l'Etablissement Aéronautique de Toulouse. M. Basseguy and M. Rio. *Tech. & Sci. Aéronautiques*, Dec., 1958, pp. 293–297. In French. Description of various facilities available at the new laboratory

of the Aeronautical Establishment in Toulouse, France.

Wind Tunnels

A Cool Mercury Plasma Tunnel. H. U. Eckert. *J. Aero/Space Sci.*, Aug., 1959, pp. 515–517. 11 refs. Discussion of radio-frequency excitation of supersonic flow as a possible means of studying effects of ionization at moderate temperatures. The heat of recombination counteracts liquefaction of the flow during expansion and permits the use of a vaporized liquid (mercury) as a testing medium.

Idées Directrices de l'Etude d'une Souffierie Transsonique. Appendix—Corrections de Parois. Robert Legendre. *La Recherche Aéronautique*, Mar.-Apr., 1959, pp. 3–8. In French. Evaluation of the basic problems leading to the modifications of the Modane wind tunnel necessary for transonic tests.

Rotating Wing Aircraft, Helicopters

French Helicopter Developments. L. F. G. Legrand. (*Helicopter Assn. Gt. Brit. Meeting, London, Apr. 10, 1959.*) *Helicopter Assn. Gt. Brit. J.*, June, 1959, pp. 157–175; Discussion, pp. 176–184. Outline of the helicopter development in France and evaluation of the Djinn and the Alouette. New designs and prototypes being presently developed are also covered.

Universal'nyi Vertolet. V. Birinlin. *Kryl'ia Rodiny*, Apr., 1959, pp. 20, 21. In Russian. Description of the Soviet helicopter Ka-15, including the rotor design, piloting, and uses.

Limited Evaluation of the H-37A Equipped with Wide Chord Blades. J. D. Davidson and W. R. Lake. *USAF FTC TR 59-14 [AD 214005]*, May, 1959. 39 pp. Test results showing that the handling characteristics are essentially the same with either blades, except for a slight improvement with the wide chord blades when operating in blade stall.

Vibrations in Helicopters: Training Considerations. R. J. Randle, Jr. *USAF WADC TN 59-61 [AD 212314]*, Mar., 1959. 7 pp. Analysis of the role of vibrations in piloting helicopters. The most important vibrations and their causes are discussed along with training considerations.

For a Cubic Concept of Warfare. D. M. Desoutter. *Aeronautics*, June, 1959, pp. 34–39. Critical discussion of the specific roles and the advantages of using large helicopters for military purposes. The use of the Westminster helicopter is stressed and its characteristics are described.

Safety

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Structural Interplay: Design and Materials. George Gerard. *Aero/Space Engrg.*, Aug., 1959, pp. 37–42. Examination of elements involved in the materials-structures problem area for compression and tension structures, and review of the nature of the interplay among these elements. Thermal protection systems are also discussed.

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Influence Coefficients for Edge-Loaded Short, Thin, Conical Frustums. J. H. Baltrukonis. (*ASME West Coast Conf. Appl. Mech. Div., Los Angeles, Sept. 8–10, 1958, Paper.*) *ASME Trans., Ser. E - AM*, June, 1959, pp. 241–245. Derivation of an exact solution in terms of Kelvin functions for a conical frustum with interacting edge loadings. Expressions for the edge-deflectional and rotational influence coefficients are presented in matrix form, and approximate expressions for the influence coefficients are evolved by using one-term asymptotic expansions for the Kelvin functions.

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K Resheniiu Dinamicheskoi Zadachi Teorii Uprugosti dlia Poluploskosti pri Smeshannykh Granichnykh Usloviiakh. V. A. Sveklo. *Prikl. Mat. i Mekh.*, Mar.-Apr., 1959, pp. 266–273. In Russian. Derivation of a solution for the dynamic problem in the theory of elasticity covering the case of a half-plane under mixed boundary conditions.

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O Zakonomernostiakh Kinetiki Deformatsii v Zavisimosti ot Podatlivosti Nagruzheniia. T. K. Zilova, N. I. Petrukhina, and Ia. B. Fridman. *AN SSSR Dokl.*, Feb. 21, 1959, pp. 1,236–1,239, 10 refs. In Russian. Description of tests performed in order to determine the kinetics of deformation in terms of the flexibility of the loading system.

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Effect of Rotary Inertia on the Frequencies of Vibration of Stiffened Plates. R. L. Thorkildsen and W. H. Hoppmann, II. *ASME Trans., Ser. E - AM*, June, 1959, pp. 298–300. Analysis showing that the effect of rotatory inertia becomes increasingly important as the vibration increases. Frequencies obtained from the analysis are compared with experimental values.

Strain-Hardening Solutions to Plate Problems. Nicholas Perrone and P. G. Hodge, Jr. (*ASME West Coast Conf. Appl. Mech. Div., Los Angeles, Sept. 8–10, 1958, Paper.*) *ASME Trans., Ser. E - AM*, June, 1959, pp. 276–284. 14 refs. Derivation of two sets of strain-hardening flow laws, called complete and direct hardening, for circular plates made of an initially Tresca material on the basis of an analogy with a kinematic model. Complete and direct-hardening solutions are obtained for three different plate problems. Results indicate that the direct-hardening solutions give a fair approximation to the complete-hardening ones.

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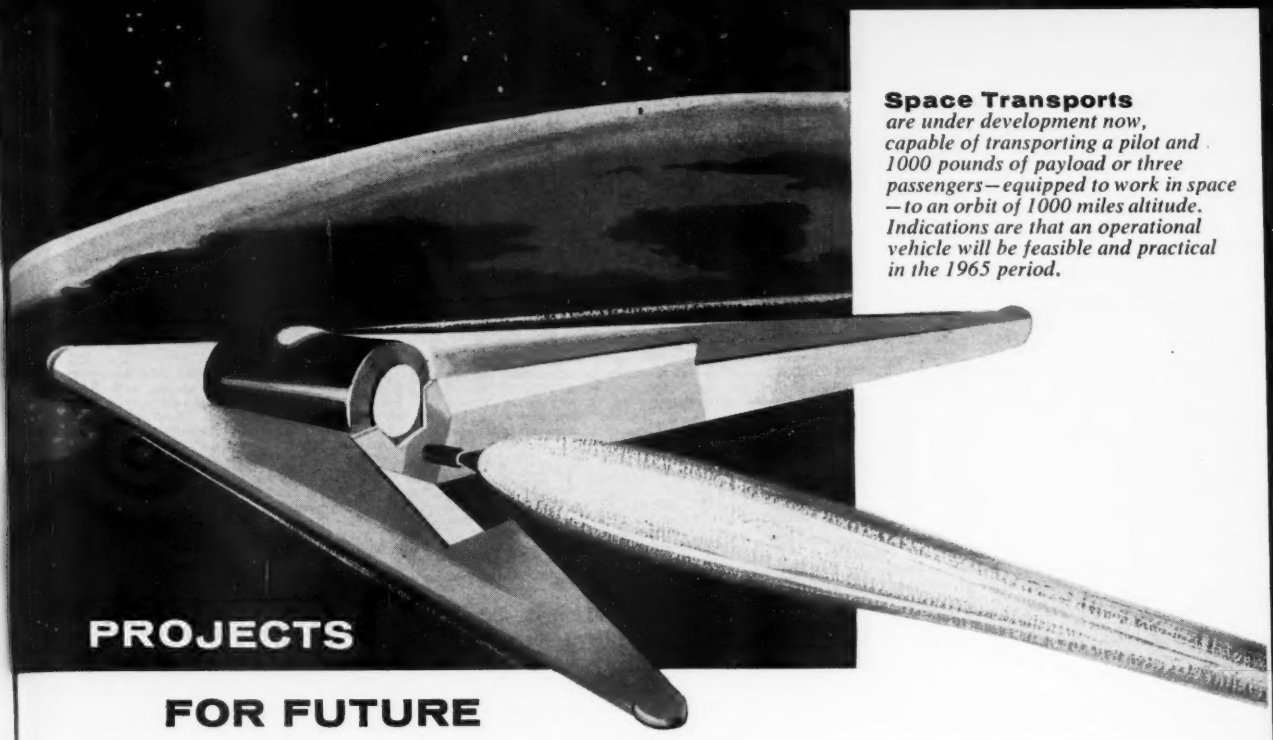

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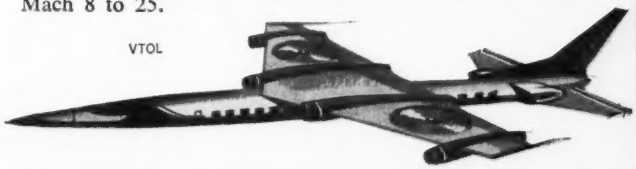
VTOL



Vertical Take-off and Landing Projects—Lockheed, Burbank, is engaged in exploring the potential of VTOL projects on a very broad scale. Different VTOL features are embodied in each proposal. Considerable emphasis is being placed on VTOL "air recovery" vehicles, designed for air rescue and reentry missiles recovery missions.

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dimensional equations for the solution of the boundary value problems are derived.

Large Deflections of a Clamped Elliptical Plate Subjected to Uniform Pressure. W. A. Nash and I. D. Cooley. *ASME Trans., Ser. E - AM*, June, 1959, pp. 291–293. Study of the deflection problem by the method of successive approximations based on the smallness of central deflection. Analytical results are shown to be in good agreement with experimental data.

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Collapse Loads of Rings and Flanges Under Uniform Twisting Moment and Radial Force. Burton Paul. (*ASME Annual Meeting, New York, Nov. 30-Dec. 5, 1958, Paper 58–A-55.*) *ASME Trans., Ser. E - AM*, June, 1959, pp. 265–270. 12 refs. Determination of the toroidal collapse on the basis of limit analysis. Interaction curves for limiting values of twisting moment and radial force are shown to have the same shape as those for limiting bending and stretching of straight beams. For rings of small uniform thickness the collapse loads are found to agree with those predicted by thin-plate theory. The theory is used to find the collapse load of thin-walled corrugated tubes under axial thrust.

Deflection of a Thick Ring in Diametral Compression by Test and by Strength-of-Materials Theory. Alexander Blake. *ASME Trans., Ser. E - AM*, June, 1959, pp. 294, 295. Brief description of experimental and theoretical deflection studies for several steel rings of uniform cross section, compressed by two forces along a diameter and having D/d ratios ranging from 1.3 to 1.9. Discrepancies between theoretical estimates and tests are shown.

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L'Analyse des Contraintes par la Méthode des Réseaux Optiques. M. Diruy. *Docaéro*, Mar., 1959, pp. 25–42. In French. Description of a method applied to the study of stresses in aircraft structures. The basic principles of the method, as well as its accuracy and range of applications are discussed.

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Optical Flame Structure Studies: Examination of Reaction Rate Laws in Lean Ethylene–Air Flames. A. Levy and F. J. Weinberg. *Comb. & Flame*, June, 1959, pp. 229–253. 24 refs. Application of temperature profiles deduced from the recorded refractive index distributions, together with measured burning velocities, to calculate the profiles of volumetric heat release rate as a first step in the analysis of flame processes.

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Hydrodynamic Characteristics of Two Low-Drag Supercavitating Hydrofoils. J. R. McGehee and V. E. Johnson, Jr. *U.S., NASA Memo. 5-9-59L*, June, 1959. 64 pp. Presentation of test results for hydrofoils of aspect ratios one and three over a range of cavitation numbers from zero to six.

Proceedings Available

The National Midwestern Meeting—Weapons System Management Proceedings (November 7, 8, 1957) contains all ***unclassified*** papers presented at the meeting.

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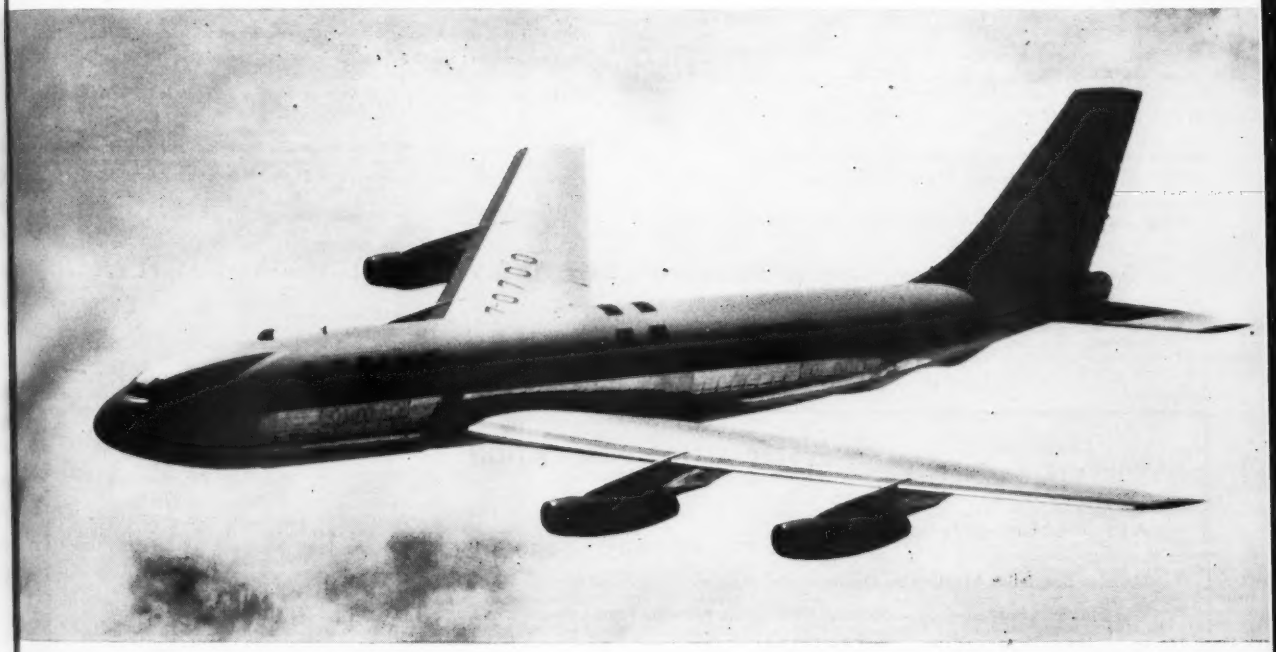

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AERODYNAMICS

Symposium on Stall, December 1–5, 1958, New York; Abstracts, References, and Figures. New York, Hydraulics Division, American Society of Mechanical Engineers, 1959. 163 pp., illus., diagrs.

The papers of the Symposium on Stall in Fluid Flow cover two areas: the consideration of fundamental aspects of stall prediction and control, and examples of actual cases wherein a rational approach to stall prediction and control has yielded gains in performance. While some of the papers are complete, most are presented in abstract form with accompanying bibliographical and graphical material intact.

Contents: Application of Boundary Layer Theory in Turbomachinery, H. Schlichting. *Part One: Basic Surveys of the State of Knowledge of Boundary Flows in Adverse Pressure Gradients:* Two-Dimensional Turbulent Boundary-Layer Behavior Under Adverse Pressure Gradient Including Separation, G. B. Schubauer. The Growth and Separation of a Turbulent Boundary Layer, G. T. Hewson. An Introduction to Three-Dimensional Boundary Flows, J. P. Johnston. Three-Dimensional Laminar Boundary Flows, A. G. Hansen. Problems of Separation in Three-Dimensional Flow, E. A. Eichelbrenner. Viscous Flow Along Corners, R. A. Oman. The Unsteady Laminar Boundary Layer, F. K. Moore. Unsteady Flow Induced by a Disk Rotating Between Parallel Plates, L. Maroti, G. Deak, and F. Kreith. Transitory Stall, S. J. Kline. Separation and Cavitation, G. F. Wislicenus. Boundary-Layer Separation in Supersonic Flow, D. M. Kuehn. Losses of Separated Flows, W. G. Cornell. Fluid Mixing by Vortex Generators, H. D. Taylor. Stabilizing Devices, S. J. Kline.

Part Two: Applications: A Discussion of Surge in Centrifugal Impellers, J. T. Hamrick. Supersonic Diffuser for Radial and Mixed Flow Compressors, F. Dallenbach and N. Van Le. Design Considerations and Performance of a 1400 ft./sec. Tip Speed Compressor Rotor, J. F. Klapproth. The Effect of Tip Clearance on the Peak Pressure Rise of Axial-Flow Fans and Compressors, L. H. Smith, Jr. Development of the Laminar-Flow Turbine Blade Profile, H. Kraft. Use of Fundamental Boundary Layer Parameters in Describing Turbine Loss Characteristics, W. L. Stewart.

Handbook of Supersonic Aerodynamics. Section 7, Three-Dimensional Airfoils. Produced and Edited by the Aerodynamics Handbook Staff of the Johns Hopkins University Applied Physics Laboratory. (NAVORD Report 1488, Vol. 3.) Washington, Superintendent of Documents, 1957. 82 pp., diagrs. $1.50.

The present section of the *Handbook*, which will eventually encompass 21 sections, presents the aerodynamic characteristics of a limited class of finite wings in a convenient form for use in design calculations. The treatment of finite wings is severely limited to uncambered wings with zero angle of attack for which thickness ratio and position of maximum thickness are held at a constant value. Theoretical airfoil characteristics for lift, pitching moment, and pressure drag are computed by the method of supersonic source distributions. They are presented in graphical form using nondimensional parameters that define the aerodynamic and geometric properties of wings in supersonic flow.

Throughout the discussion, theoretical analyses are reduced to a minimum consistent with intelligent use of the data, and a reference is made to the original sources containing the more detailed analyses. Sample calculations are included to demonstrate the practical use of the graphs in determining the aerodynamic characteristics of several wing configurations at specified flight conditions. A brief comparison of theory and experiment is included in order to provide a convenient basis for estimating the accuracy and reliability of theoretical predictions from the linearized theory.

AERONAUTICS, GENERAL

1959 Annual Forecast of Trends and Requirements. Los Angeles, Aerospace Industries Association of America, Inc., 1959. 50 pp., diagrs., tables.

This is the sixth Annual Forecast prepared by the Aerospace Industries Association for distribution to the Department of Defense, other Government agencies, and industries serving the aerospace complex. The report is based on information supplied by the various AIA member companies and was compiled by the Research and Testing Committee, and by the Manufacturing Equipment, Tooling, and Test Committees.

The 1959 report is divided into two parts: *Part One* presents the engineering interpretation of future trends and requirements; *Part Two* presents the corresponding required developments in manufacturing technology.

CONTROL THEORY

Servomechanisms and Regulating System Design, Vol. 1. Harold Chestnut and Robert W. Mayer. 2nd Ed. New York, John Wiley & Sons, Inc., 1959. 680 pp., diagrs., tables. $11.75.

First appearing in 1951 and designed to train design and application engineers in the basic principles of feedback control, the present volume has been prepared to reflect recent advances in the field. Added features include: new chapters on the application of root-locus to the analysis and synthesis of control system design, and the use of an analog computer for the solution of control systems problems; feedback nomenclature and definitions that have been brought into accordance with current practice; a modified presentation of transfer function material to emphasize the loading effect of one element on another; additional supplemental ways of relating open-loop frequency response to approximate closed-loop transient response; and revised material covering error coefficients.

Both authors are with the General Electric Company.

Control Engineering. Gordon J. Murphy. Princeton, N.J., D. Van Nostrand Company, Inc., 1959. 385 pp., diagrs., tables. $7.50.

Both elementary and advanced topics are treated in detail. The subject matter is presented at an intermediate level with problems and illustrations drawn from many fields, such as process control, fire control, inertial guidance, and nuclear reactor control. Some of the topics chosen for discussion include: time response, a development of Laplace transformations, characteristics of a large number of control-system components, design in the complex domain (the *s*-plane), the use of frequency-response techniques, a-c carrier systems, the analysis of systems with time lag, sampled-data systems, the statistical analysis of linear control systems, and nonlinear control theory.

Dr. Murphy is Associate Professor of Electrical Engineering and Industrial Engineering, Northwestern University. A more advanced treatment of many of these topics appears in his earlier book, *Basic Automatic Control Theory*.

DICTIONARIES

Russian-English Atomic Dictionary: Physics, Mathematics, Nuclear Science, and Technology. Eugene A. Carpovich. 2nd Ed. Technical Dictionaries Co., P.O. Box 144, New York 31, N.Y., 1959. 317 pp. $12.

The dictionary comprises over 23,000 Russian entries, arranged in a single alphabetical listing It covers primarily: nuclear science and technology, including theory, reactors, instrumentation, and isotopes; physics, including theoretical, atomic, and molecular physics, physics of solids, and crystallography; mathematics, including algebra, geometry, trigonometry, analytic and differential geometry, differential and integral calculus, differential equations, vector analysis, tensors, various functions, matrices, group theory, statistics, probability theory, and processing of experimental data. The dictionary covers also many terms from chemistry and chemical engineering: chemistry of U, Th, Be, Zr; radiation chemistry; isotopes separation; nuclear applications; metallurgy of certain metals used in nuclear technology; gamma-ray metallography; peaceful and military uses of the atom, including isotopic tracers in research, industrial atomic power, atomic propulsion, and nuclear weapons; biophysics and radiobiology, radiation instruments, radiology, and genetics.

Also included are miscellaneous scientific terms used in computation, automatic control, electronics, library practice, publishing and printing, and other similar fields; Russian transliteration of Western names frequently encountered in atomic publications; and abbreviation of atomic and related terms.

Atomterminologie (Atomic Terminology); English-German-French-Italian, Band 1. Lore Lettenmeyer. Munich, Max Hueber Verlag, 1958. 298 pp. DM 24.80., $5.90.

The dictionary provides a selection of 1,814 essential scientific and technical terms employed in connection with atomic and nuclear physics, reactor engineering, radiation physics, and associated fields. These are listed in alphabetical order in English and numbered consecutively, with their German, French, and Italian equivalents given in parallel columns with the same consecutive numbers. The main section is followed by alphabetically arranged German, French, and Italian indexes listing the terms with the numbers under which the corresponding terms in the other three languages will be found in the main section. Where a term consists of more than one word, it is listed in the alphabetical index under each of its components—e.g., "langsames Neutron" under "langsam" and "Neutron."

ELECTRICITY

Topics in Electromagnetic Theory. Dean A. Watkins. New York, John Wiley & Sons, Inc., 1959. 118 pp., diagrs. $6.50.

The volume presents logical, unified treatment of several topics in the field of electromagnetic theory and microwave electron tubes, including periodic transmissions systems, propagation on a wire helix, coupling of modes of propagation, and anisotropic media and the waves that propagate therein.

Dr. Watkins, Professor of Electrical Engineering, Stanford University, has developed the book from a set of lecture notes organized for a graduate course in electrical engineering.

The Physics of Electricity and Magnetism. William Taussig Scott. New York, John Wiley & Sons, Inc. 635 pp., diagrs., tables. $8.75.

This book provides a thorough explanation of the basic theory of electricity and magnetism, treated in a rigorous manner from the viewpoint of a physicist. A modern atomic approach is used to describe phenomena such as metallic conduction and the production of chemical and thermal emfs. The analysis of magnetic fields starts with the Lorentz force law, and Maxwell's equations are introduced as an integral part of the text, with a chapter at the end on their applications. The fully descriptive yet mathematical treatment that is provided (using vector notation and intermediate calculus) serves as a transition to more advanced work in physics.

Dr. Scott, Professor of Physics, Smith College, has compiled the material as a text suitable for seniors and first-year graduates.

MATERIALS

High Temperature Materials; Conference Held in Cleveland, Ohio, April 16–17, 1957. Edited by R. F. Hehemann and G. Mervin Ault. Sponsored by High Temperature Alloys Committee, Institute of Metals Division, The Metallurgical Society, American Institute of Mining, Metallurgical, and Petroleum Engineers. New York, John Wiley & Sons, Inc., 1959. 544 pp., illus., diagrs., tables. $17.50.

Contents: Part I, Cobalt- and Nickel-Base Alloys. (1) Status and Future of Nickel-Base Alloys, F. L. Ver Snyder. (2) Investigation of High-Temperature Properties of Nickel-Base Alloys Using Balanced-Experiment Designs, T. L. Robertshaw. (3) Evaluation of a Cast Nickel-Base Alloy for Use as a Bucket Material at 1,650°F, R. A. Signorelli, J. R. Johnston, and J. W. Weeton. (4) W545—A New Higher Temperature Turbine Disk Alloy, J. T. Brown and J. Bulina. (5) History, Status, and Future of Cobalt Alloys, G. A. Fritzlen. (6) ML—1700 Cast Turbine Bucket Alloy, R. J. Morris. (7) Temperature Dependence of the Hardness of Secondary Phases Common in Turbine Bucket Alloys, J. H. Westbrook.

Part II, Cermets and Intermetallics. (8) Cermets and Bonded Hard Metals, J. T. Norton. (9) Recent Developments in Sintered Titanium Carbide Compositions, J. Wambold and J. C. Redmond. (10) Recent Advances in Infiltrated Titanium Carbides, H. W. Lavendel and C. G. Goetzel. (11) Wettability and Microstructure Studies in Liquid-Phase Sintering, N. M. Parikh and M. Humenik, Jr. (12) Modes of Fracture and Slip in Cemented Carbides, N. M. Parikh. (13) Materials Based on Intermetallic Compounds, R. Steinitz. (14) The Use of Cermets as Gas-Turbine Blading, G. C. Deutsch.

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Part VI, Effect of Testing Environment on Properties. (28) The Effect of Environment on High-Temperature Creep Properties of Metals and Alloys, D. A. Douglas. (29) A Comparison of the Creep-Rupture Properties of Nickel in Air and in Vacuum, P. Shahinian and M. R. Achter. (30) Effect of Environments of Sodium Hydroxide, Air, and Argon on the Stress-Rupture Properties of Nickel at 1,500°F., H. T. McHenry and H. B. Probst. (31) The Effect of Testing Atmosphere on the Creep-Rupture Properties of Molybdenum-Base Alloys at 1,800°F., D. D. Lawthers and M. J. Manjoine.

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Molecular Science and Molecular Engineering. Arthur R. von Hippel. New York, John Wiley & Sons, Inc., 1959. 446 pp., illus., diagrs. $18.50.

Contents: (1) Macroscopic Laws and Molecular Interpretations, A. von Hippel. (2) Formation and Structure of Atoms and Molecules, A. von Hippel. (3) Conduction and Breakdown of Gases, A. von Hippel. (4) Thunderstorms and the Electrical State of the Atmosphere, J. P. Kuettner. (5) Microwave Breakdown, S. C. Brown. (6) Gas Discharges as Technical Devices, E. O. Johnson. (7) Explosions in Gaseous Systems, B. Lewis. (8) Gases, Liquids, and Solids, O. K. Mawardi and A. von Hippel. (9) Building Laws for Condensed Phases, A. von Hippel. (10) Reaction Mechanisms in Liquid Systems, C. G. Swain. (11) Molecular Synthesis of Polymers, W. H. Stockmayer. (12) Growth and Perfection of Single Crystals, A. Smakula. (13) Irradiation Effects in Materials, R. Smoluchowski. (14) The Plasticity of Crystalline Materials, E. Orowan. (15) Dipoles and Coupled Dipole Systems; Ferroelectrics and Ferromagnetics, A. von Hippel. (16) Ferro- and Antiferroelectric Materials, P. W. Forsbergh, Jr. (17) Piezo- and Ferroelectric Devices, W. P. Mason. (18) Ferromagnetic Materials and Molecular Engineering, D. J. Epstein. (19) Ferromagnetic Devices, R. A. Ramey, Jr., and B. W. Lovell. (20) Parametric Amplifiers, Masers, and Film Memories: Molecular Generators and Amplifiers, J. W. Mayer; Magnetic Films for Computer Memories, D. O. Smith. (21) Mobilization of Charge Carriers in Liquids and Solids, A. von Hippel. (22) Polyelectrolytes, R. M. Fuoss. (23) Ion-Exchange Resins, C. D. Coryell. (24) Rectifiers and Transistors, R. B. Adler. (25) Molecular Engineering and the Air Vehicles of the Future, K. Martinez. Table of Symbols. Index.

The Solid State for Engineers. Maurice J. Sinnott. New York, John Wiley & Sons, Inc., 1959. 522 pp., illus., diagrs., tables. $12.50.

This book will acquaint engineers and students with the basic principles which underlie the behavior of solid materials. It aims to bridge the gap between the handbook type of material concerned with the manufacture or use of materials, and the solid state physics text books concerned with the deduction of general laws of behavior.

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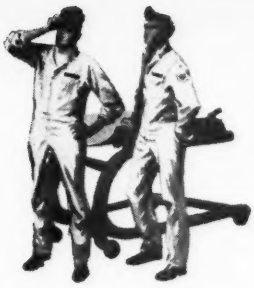

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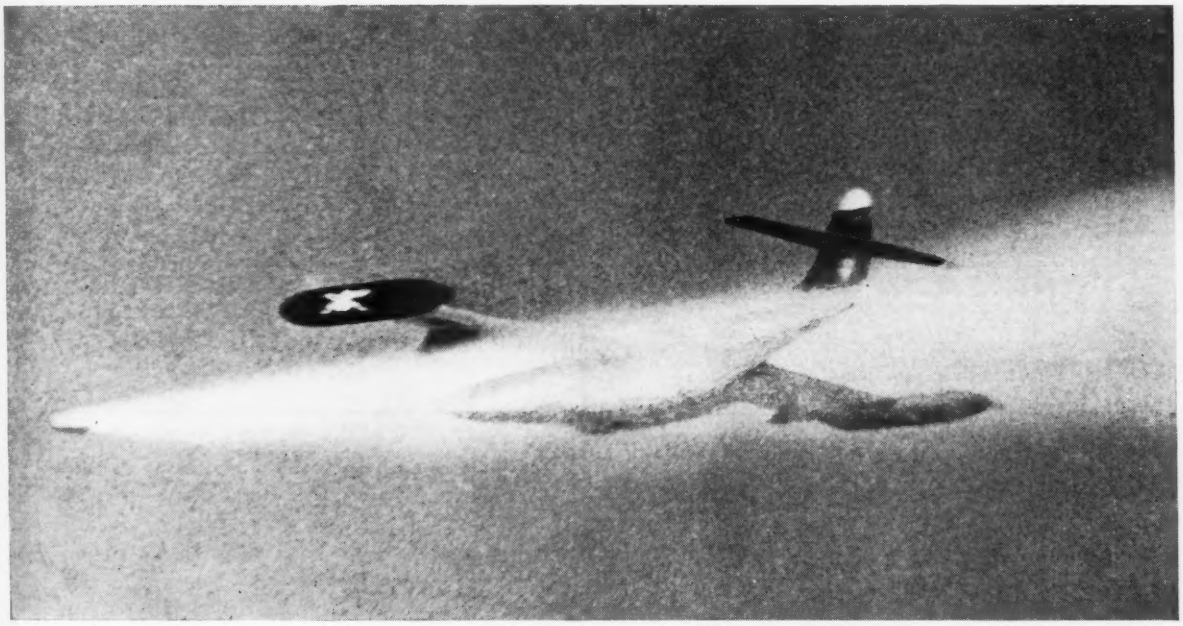

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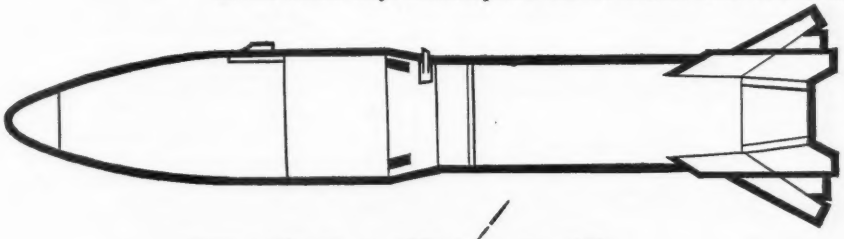

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The Structure of Metals, A Modern Conception; Lectures Delivered at the Institution of Metallurgists Refresher Course, 1958. London, Iliffe & Sons, Ltd.; New York, Interscience Publishers, Inc., 1959. 118 pp., illus., diagrs. $4.00.

Contents: (1) The Electron Structure of Metals, G. V. Raynor. (2) Experimental Aspects of the Electron Theory of Metals, J. A. Catterall. (3) Dislocations in Metals, A. G. Quarrell. (4) Seeing Dislocations, J. Nutting. Index.

MILITARY AVIATION

The Soviet Air and Rocket Forces. Edited by Asher Lee. New York, Frederick A. Praeger, 1959. 311 pp., illus. $7.50.

Contents: (1) The Civil War to the Second World War, G. Schatunowski. (2) From Barbarossa to Stalingrad, W. Schwabedissen. (3) From Stalingrad to Berlin, P. Williams. (4) Soviet Air Strategy in the Second World War, H. Baldwin. (5) Post-War Strategy, K. Whiting. (6) Long Range Air Attack, P. Joubert. (7) Strategic Air Defence, A. Lee. (8) The Development of Jet Fighters and Fighter Bombers, W. Green. (9) Soviet Missiles, A. Lee and R. E. Stockwell. (10) Soviet Airborne Troops, J. M. Mackintosh. (11) Soviet Air Power: Organization and Staff Work, R. L. Garthoff. (12) The Training of Personnel, G. Schatunowski. (13) Politics in the Soviet Air Force, B. Kuban. (14) Daily Life in the Soviet Air Force, B. Kuban. (15) The German Legacy, R. E. Stockwell. (16) Soviet Aircraft Production, R. E. Stockwell. (17) Soviet Civil Aviation, K. Whiting. (18) The Air Allies of the USSR, A. Lee. (19) The Future of Soviet Air Power, A. Lee. Biographical Notes of Contributors. Index.

PHYSICS

Introduction to Mathematical Physics. William Band. Princeton, N. J., D. Van Nostrand Company, Inc., 1959. 326 pp., diagrs. $7.25.

This text, by a Professor of Physics at Washington State University, is designed for use in courses on theoretical physics for college senior and graduate students. Its purpose is to introduce to the student the most powerful mathematical tools available today, and to survey theoretical physics from a modern unified point of view. Some of the special topics discussed include: the methods and concepts of linear algebra and function space; the theory of shock waves; random motion; multipole fields; Green's method for inhomogeneous differential equations (source functions); the basic concepts of Einstein's theory of gravitation; and relativistic quantum mechanics.

RESEARCH

Second Annual Report, Air Force Office of Scientific Research, 1957. (AFOSR TR 58-71, AD 158300.) Washington, Air Force Office of Scientific Research, Air Research and Development Command, U. S. Air Force, July, 1958. 222 pp.

This report covers the accomplishments of the exploratory research program supported by the AFOSR (ARDC) during 1957. It is in three parts: (1)—The Commander's Summary, reviewing the year's highlights; (2)—Text, giving detailed results of the research contracts monitored by the Directorates: Advanced Studies, Aeronautical Sciences, Bio Sciences, Material Sciences, Physical Sciences, Research Communication, and their Technical Divisions: Aeromedicine, Behavioral Sciences, Chemistry, Combustion Dynamics, Mathematics, Mechanics, Nuclear Physics, Physics, and Solid State Sciences; and (3)—an appendix listing AFOSR consultants and research contracts, indexed by contractor and investigator.

RUSSIAN LANGUAGE

Russian for the Scientist. John Turkevich and Ludmilla B. Turkevich. Princeton, N.J., D. Van Nostrand Company, Inc., 1959. 255 pp. $5.95.

This text is designed for the English-speaking scientist, and its aim is to furnish this scientist with the means for extracting the particular information he seeks from Russian scientific literature. The material is presented in such a way as to develop a knack for recognition as well as familiarity with the basic points of grammar. While most essentials are included, the stress is almost entirely on scientific usage.

A practical feature of the book is the use of a scientific vocabulary in the Russian-English and English-Russian exercises from the very beginning, rather than the general vocabulary usually employed in exercises of this type. The readings begin with simplified chemistry texts and progress to unedited selections drawn from Soviet encyclopedias and textbooks in aeronautical engineering, biology, physics, and chemistry.

Dr. John Turkevich is Eugene Higgins Professor of Chemistry, Princeton University. Mrs. Turkevich is Lecturer in Russian at the same institution.

SAFETY

Survey of Research Projects in the Field of Aviation Safety; 1959 Annual Supplement. New York, The Daniel & Florence Guggenheim Aviation Safety Center at Cornell University, 1959. 85 pp.

The directory lists information on more than 600 research projects conducted in various fields affecting aviation safety. Over 130 new research projects are reported in this year's survey, which includes programs in progress in the U.S., Canada, Great Britain, France, and the Netherlands. Encompassing both military and civil aviation, the information given for each entry includes the title of the project, a description of the work being done, the sponsor and location, and a serial number for identification purposes. Further information on any project can generally be obtained directly from the responsible sponsor or laboratory.

SPACE TRAVEL

Man in Space; The United States Air Force Program for Developing the Spacecraft Crew. Edited by Kenneth F. Gantz. New York, Duell, Sloan and Pearce, 1959. 303 pp., illus., diagrs. $4.00.

With one exception, the chapters in this book, which is intended to give a professional review of the current investigations of the U.S. Air Force into manned space flight, were originally composed for publication in the *Air University Quarterly Review*. The fourth chapter, by Brigadier General Don Flickinger, was edited from his lecture in Denmark, October 23, 1958, before the NATO Advisory Group for Aeronautical Research and Development (AGARD).

Contents: The Inevitable Climb to Space, T. D. White. The Threshold of Space, D. C. Ogle. From Aviation Medicine to Space Medicine, H. Strughold. Basic Factors in Manned Space Operations, H. Strughold. Biomedical Aspects of Space Flight, D. Flickinger. Biodynamics of Space Flight, J. P. Stapp. The Engineered Environment of the Space Vehicle, H. G. Clamann. Human Performance in Space, G. T. Hauty. Weightlessness, S. J. Gerathewohl. Observations in High-Altitude, Sealed-Cabin Balloon Flight, D. G. Simons. Human Requirements for Space Flight, S. B. Sells and C. A. Berry. Experimental Studies on the Conditioning of Man for Space Crews, B. Balke. Escape and Survival During Space Operations, P. A. Campbell. Time Dilation and the Astronaut, E. R. Goltra. The Spiral Toward Space, By the Editors of *Air University Quarterly Review*. Human-Factors Support of the X-15 Program, B. Rowen. The U.S. Air Force Human-Factors Program, D. Flickinger. Blueprints for Space, H. A. Boushey. The Military Impact of Manned Space Operations, L. P. Hopwood. Reference Notes.

Appendices: (1) A Glossary of Terms Related to the Human Factor in Space Operations, R. W. Bancroft and H. G. Clamann. (2) A Reading List of Books on Astronautics, R. Estep. (3) The Contributors: Biographical Notes. (4) Project Mercury and the National Space Program, K. F. Grantz. Index.

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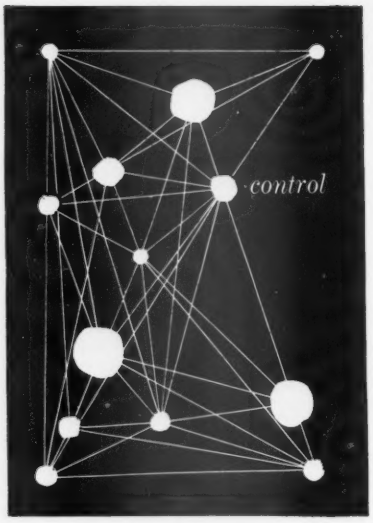

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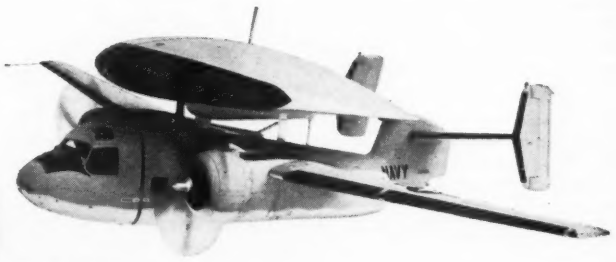

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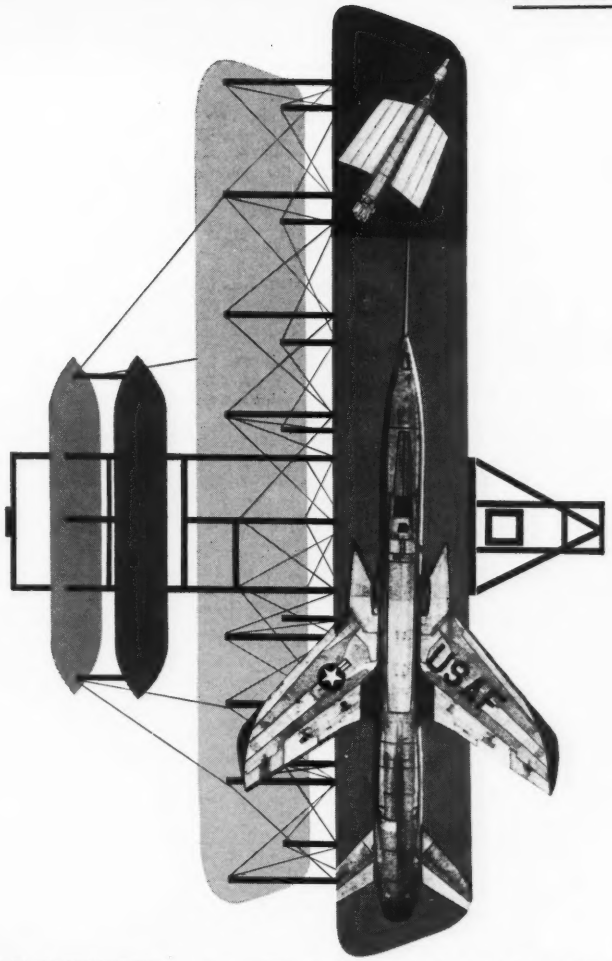

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